Effect of Body Mass Index on Cardiac Autonomic Functional Status in Healthy Young Adults

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ABSTRACT

Introduction: Autonomic nervous system (ANS) is involved in energy metabolism and regulation of the cardiovascular system. Autonomic dysfunction has been suggested to occur in obese individuals in both adults and children but a comprehensive study of the autonomic status in young adults is scant. So aim of the study was to evaluate and compare cardiovascular autonomic functions in young adults on the basis of BMI.

Material and methods: 150 healthy young students of MMU aged 18–25 years, divided into four groups based on BMI as per Asian criteria (underweight, normal weight, overweight and obese). Various autonomic function tests done were Lying to Standing test, Valsalva manoeuvre, Hand grip test (HGT) and Cold pressor test (CPT).

Results: The mean baseline SBP and DBP were significantly higher in obese subjects followed by overweight, normal weight and under weight. No parasympathetic alteration between different BMI groups was seen. Mean values of resting SBP and DBP were significantly higher and blood pressure response to HGT and CPT was significantly lower in obese as compared to normal weight subjects.

Conclusion: Our study revealed an altered autonomic function in the form of impaired sympathetic activity with no parasympathetic modulation in obese young adults. So weight reduction and moderate intensity aerobic exercise programmes should be incorporated into daily living, which may delay or prevent the onset of hypertension.

Keywords: Obesity; Body Mass Index (BMI); Lying to Standing test; Valsalva manoeuvre; Hand grip test (HGT); Cold pressor test (CPT).

INTRODUCTION

Obesity is a condition characterized by the excessive accumulation and storage of fat in the body which increases risk to health. Obesity is now recognized as a chronic or non-communicable disease. The fundamental cause of obesity and overweight is an energy imbalance between calories consumed and calories expended. Globally, there has been: i) an increased intake of energy-dense foods that are high in fat; and ii) an increase in physical inactivity due to the increasingly sedentary nature of many forms of work, changing modes of transportation, and increasing urbanization.

With the continued rise in standards of living, obesity is emerging as a global epidemic in both children and adults. This has been called "New world syndrome" and is a reflection of massive social, economic and cultural problems currently faced by developing and developed countries.[1]

Worldwide 39% of adults aged 18 years and over were overweight in 2016, and 13% were obese. Over 340 million children and adolescents aged 5-19 were overweight or obese in 2016.[2]

Childhood and adolescence obesity is a harbinger of obesity in later life.[3] Being overweight in childhood and adolescence is associated with greater risk and earlier onset of chronic disorders[4-6] such as Hypertension, Diabetes. and has adverse psychosocial consequences and lowers educational attainment.[7] Obese persons suffer from an increased mortality risk due to cardiovascular complications.[8]

Autonomic nervous system (ANS) is involved in energy metabolism and regulation of the cardiovascular system.[3,4] It is conceivable that one or more subgroups of obesity have an alteration in their ANS that may promote obesity and account for several clinical consequences of obesity.[9,10]

Several studies have suggested that autonomic dysfunction occurs in obese individuals.[11,12] The activity of sympathetic nervous system is a determinant of energy expenditure. It has been observed that individuals with low resting muscle sympathetic nerve activity may be at risk for body weight gain resulting from a lower metabolic rate.[13]

Obesity was found to be associated with decreased sympathetic activity in animal models. Experimentally induced ventro-medial hypothalamic lesions resulted in decreased sympathetic activity, increased parasympathetic activity and obesity.[10] Overfeeding is found to be associated with sympathetic activation and there is evidence that adrenergic mechanisms contribute to cardiovascular complications.[14]

Various studies[15] are available that reveal the indirect role of ANS in obesity but a comprehensive study of the autonomic status in young adults is scant children.

So, the present study was attempted to evaluate and compare cardiovascular autonomic functions in young adults on the basis of BMI.

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MATERIAL AND METHODS

A total of 150 healthy young adults were included in this study with age range from 18 to 25 years. The study was conducted in the Department of Physiology at Maharishi Markandeshwar Institute of Medical Sciences and Research, Mullana (Ambala). The study was approved by the Institutional ethical committee. Informed and written consent of all the participants was taken before conducting the study. The non-smoker, non-alcoholic, with systolic (SBP) and diastolic blood pressure (DBP) < 140/90 mm/Hg were included in the study. Exclusion criteria included i) Subjects with SBP ≥ 140 and or DBP ≥ 90 mm/Hg ii) Subjects on antihypertensive drugs or any other medication. iii) Under-going regular physical training. iv) With history of acute or chronic illness like diabetes mellitus, renal disease or any neuro-psychiatric disorder which can affect autonomic function.

Measurement of BMI

Body Mass Index (BMI) was calculated as Body weight in kilograms divided by square root of Body height in meter, using Quetelet index.[16] **Normal weight** was defined as BMI 18.5 to ≤ 22.9, **Under weight** as BMI < 18.5, **Overweight** as BMI 23 to ≤ 24.9 and **Obesity** as BMI ≥ 25 kg/m^2, as per revised body type classification for Indian Population recommended by Health ministry and Diabetes Foundation of India in 2008.[17]

Subjects were divided into four groups based on BMI as per Asian criteria.

Under weight	N=13(9%)
Normal weight	N=66(44%)
Overweight	N=25(16%)
Obese	N=46(31%)

A detailed history was taken and general physical examination of all the volunteers was done. with the main emphasis on cardiovascular diseases, renal diseases. None of the subjects took any medication at the time of the study. All the students were explained about the procedure of tests and tested under similar laboratory conditions in comfortable environment. Subjects were instructed not to have heavy meals/tea/coffee at least 2 hours before the test and were asked to rest just before the commencement of the test, and then all basal parameters like heart rate, blood pressure and respiratory rate were measured. Various Cardiovascular Autonomic function tests that were performed are as follows.

TESTS OF CARDIOVASCULAR AUTONOMIC FUNCTION

Parasympathetic tests

1. Heart rate response to Standing.
2. Heart rate changes during the Valsalva manoeuvre.

Sympathetic tests

1. Blood pressure response to sustained Hand Grip Test.
2. Blood pressure response to Cold Pressor Test.

Heart rate response to Standing (Lying to Standing test)

In this test heart rate response to standing was assessed. Each subject initially took supine rest on a couch for 5 min; ECG limb leads were attached, baseline ECG was recorded. Then subject attained standing posture within 3 seconds. A continuous ECG (lead II) was recorded during the procedure for measuring heart rate. 30:15 ratio was calculated as the ratio of the longest R-R interval at or around 30th beat after standing / shortest R-R interval at or around 15th beat after standing. The normal value of 30:15 ratio is ≥ 1.04.[18]

Heart rate changes during the Valsalva manoeuvre (Valsalva Ratio)

The test was done in a sitting posture. The subject blows into a mouth piece attached to sphygmomanometer to raise the pressure to 40 mmHg for 15 seconds. At the end of 15 seconds, the pressure was released. A continuous ECG (lead II) was recorded 1 minute before the manoeuvre, during the manoeuvre and 40 seconds following the release of strain period. Valsalva Ratio is calculated as the ratio of the longest R-R interval after the strain / shortest R-R interval during the strain. The normal value of Valsalva Ratio is > 1.21.[18]

Blood pressure response to sustained Hand Grip Test (HGT)

The baseline blood pressure was recorded. The subject was asked to press handgrip dynamometer at 30% of maximum voluntary contraction (MVC) for 15 seconds. Blood pressure was recorded just before the release of hand grip after 1 minute and 5 min of grip release. Maximum rise in diastolic blood pressure above baseline was noted. A rise of more than 10 mmHg in diastolic blood pressure after the test was considered normal.[19]

Blood pressure response to Cold Pressor Test (CPT)

First, the baseline blood pressure was recorded and then the subjects were instructed about the test. They were instructed to indicate to the investigator if they were not able to keep the hand immersed in water for 1 minute. The cold water of 10^{o}C was prepared. Subject immersed the right hand in cold water up to the wrist without touching the bottom of cold water bath, for 1 minute. After that hand was removed from water, it was covered by the towel. The blood pressure was recorded from left hand just at the end of 1 minute of immersion and again at 1 minute after hand was withdrawn from the cold water. A rise of 10mmHg in diastolic blood pressure after test was considered normal.[18]

Each test was performed after a resting period of 10 minutes, in a supine or sitting position. Blood Pressure recording was done by using an Omron (SEM 1 Model), the automatic blood pressure monitor (Omron Healthcare Co. Ltd, Kyoto, Japan). The heart rate was measured from R-R interval of ECG using lead II of Electrocardiograph machine (CADIART 108T-DIGI, BPL LIMITED). Hand grip strength was measured from Handgrip Dynamometer.

STATISTICAL ANALYSIS

The collected data was tabulated and analyzed with the help of Statistical Package for Social Sciences SPSS for WINDOWSTM (version 20). Student's independent t-test for quantitative differences was used for data analysis. The inter-group comparison was done by one way ANOVA with post hoc test. Mean ± standard deviations were calculated and t-test was applied for measuring statistical significance in the difference of means. $P < 0.05$ was considered statistically significant and $P \leq 0.001$ was considered highly significant.

RESULTS

Various groups of BMI were comparable for age and gender. On comparison of mean basal parameters (heart rate and blood pressure) between various BMI groups, the mean basal heart rate was similar between obese, overweight and normal weight subjects. While mean SBP and DBP

	Under weight N=13	Normal weight N=66	Overweight N=25	Obese N=46	*P* value*
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Basal heart rate(beats/min)	82.37 ± 10.15	82.37 ± 10.15	82.37 ± 10.15	78.66 ± 9.53	0.052
Basal systolic pressure (mm/Hg)	106.76 ±10.54	108.68 ±10.48	111.50 ± 9.83	116.91 ± 11.64 #•▲	0.002
Basal diastolic pressure (mm/Hg)	68.46 ± 7.86	64.71 ± 5.75	69.36 ± 6.85	75.26 ± 7.55 #•▲	0.008

*P-value <0.05 is considered statistically significant
# indicates significant difference ($P < 0.05$) on intergroup comparison with Underweight.
● indicates significant difference ($P < 0.05$) on intergroup comparison with Normal weight.
●● indicates significant difference ($P \leq 0.001$) on intergroup comparison with Normal weight.
▲ indicates significant difference ($P < 0.05$) on intergroup comparison with Overweight.

Table-1: Comparison of basal parameters between different groups according to BMI

	Under weight N=13	Normal weight N=66	Overweight N=25	Obese N=46	*P* value*
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Lying to standing test					
R-R interval at 30th beat	15.85 ± 2.76	16.47 ± 2.45	16.52 ± 2.96	16.72 ± 2.74	0.776
R-R interval at 15th beat	12.46 ± 1.90	13.17 ± 1.85	12.96 ± 2.52	13.00 ± 1.98	0.713
30:15 ratio	1.31 ± 0.21	1.26 ± 0.12	1.33 ± 0.19	1.29 ± 0.15	0.209
Valsalva manoeuvre					
longest R-R interval after the strain	20.62 ± 2.93	21.36 ± 3.10	20.24 ± 3.98	21.50 ± 3.20	0.384
shortest R-R interval during the strain	11.38 ± 1.61	12.88 ± 2.06	12.44 ± 2.06	12.64 ± 1.96	0.103
Valsalva Ratio	1.84 ± 0.36	1.68 ± 0.27	1.67 ± 0.32	1.71 ± 0.23	0.279

*P-value <0.05 is considered statistically significant

Table-2: Comparison of Parasympathetic tests between different groups according to BMI

	Under weight (N=13)	Normal weight (N=66)	Over weight (N=25)	Obese (N=46)	*P* value*
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Hand grip test (HGT)					
SBP Before HGT	107.46 ±10.78	108.48 ±10.28	110.40 ± 9.23	115.98 ± 11.74 #••▲	0.002
SBP After HGT	127.92 ±15.58	129.82 ± 14.32	130.88 ± 14.78	134.43 ± 16.00 #•▲	0.027
SBP Difference HGT	20.46 ± 9.73	22.97 ± 10.77	20.44 ± 8.70	18.17 ± 11.40 •	0.480
DBP Before HGT	68.46 ± 7.96	65.71 ± 6.75	68.36 ± 7.81	71.26 ± 8.65 ••	0.003
DBP After HGT	85.31 ± 10.84	84.05 ± 10.79	84.60 ± 12.49	85.11 ± 12.26	0.319
DBP Difference HGT	16.77 ± 8.39	18.55 ± 8.71	16.24 ± 7.86	14.74 ± 8.69 •	0.067
COLD pressor test (CPT)					
SBP Before CPT	106.38 ±10.10	107.45 ± 9.32	112.12 ± 8.95	115.63 ± 11.67 #••	**<0.001**
SBP After CPT	125.00 ±12.05	126.42 ± 13.15	127.68 ± 11.57	130.46 ± 13.03 •	0.067
SBP Difference CPT	18.62 ± 8.03	19.06 ± 8.31	15.56 ±8.65	14.85 ± 7.22 •	0.048
DBP Before CPT	67.31 ± 7.43	64.82 ± 6.44	68.12 ± 7.46 •	70.52 ± 7.63••	0.001
DBP After CPT	81.92 ± 10.55	80.56 ± 9.07	83.68 ± 10.75	83.59 ± 2.66 •	0.046
DBP Difference CPT	14.62 ± 7.96	15.74 ± 5.16	15.60 ± 6.36	13.07 ± 6.29 •▲	0.039

*P-value <0.05 is considered statistically significant.
Inter group comparison was done by one way ANOVA with post hoc test.
# indicates significant difference ($P < 0.05$) on intergroup comparison with Underweight.
● indicates significant difference ($P < 0.05$) on intergroup comparison with Normal weight.
●● indicates significant difference ($P \leq 0.001$) on intergroup comparison with Normal weight.
▲ indicates significant difference ($P < 0.05$) on intergroup comparison with Overweight.

Table-3: Comparison of Sympathetic tests among different groups according to BMI were significantly higher in obese subjects followed by overweight, normal weight and under weight ($P < 0.05$) as shown in Table 1.

Comparison of Parasympathetic tests i.e. Lying to Standing test between different groups according to BMI i.e. underweight, normal weight, overweight and obese did not reveal significant difference as shown in Table 2. Similarly in the Valsalva manoeuvre, the mean of Valsalva ratio for different groups was not statistically significant ($P = 0.279$). Inter group comparison of 30:15 ratio and Valsalva ratio done by one way ANOVA with post hoc test did not reveal a significant difference, indicating that there is no significant change in parasympathetic activity with an increase in BMI.

Table 3 shows that the mean SBP before HGT was highest for obese (115.98 ± 11.74mm/Hg), then for overweight (110.40 ± 9.23 mm/Hg), followed by normal weight and under weight. The difference was found to be statistically significant ($P = 0.002$). Mean DBP before HGT was found to be significantly raised in obese than in normal weight subjects. The inter group comparison of *P* values of SBP and DBP before HGT is highly significant for normal weight vs obese subjects. ($P = 0.001$) while between normal weight vs overweight it is significant ($P < 0.05$). Inter group comparison of SBP and DBP difference HGT is significantly lower for obese group as compared to normal weight.

In case of CPT, SBP before CPT was found highest in obese subjects (115.63 ± 11.67 mm/Hg), followed by overweight subjects (112.12 ± 8.95 mm/Hg) than in normal weight subjects (107.45 ± 9.32 mm/Hg). A statistically significant difference was found between the groups ($P < 0.001$). Similarly, DBP before and after CPT was found to be highest in obese than other subjects. But comparison of mean SBP and DBP difference CPT between different groups was statistically significant. On inter group comparison, P value of SBP and DBP difference CPT is significantly lower for obese subjects as compared to normal weight ($P < 0.05$). The above results indicated that in obese subjects increased sympathetic activity at resting condition is seen and there is a statistical significant difference in sympathetic response to stressor as compared to normal weight subjects.

DISCUSSION

The present study examined the effect of BMI on cardiac autonomic activity. Evaluation of status of the autonomic nervous system was assessed with the help of various non-invasive tests like Lying to Standing test, Valsalva maneuver, sustained Hand grip test and Cold pressor test. Evaluation of parasympathetic system tests primarily provide an index to cardiac vagal functions. While sympathetic tests are of prognostic importance to determine sympathetic reactivity.

The findings of our study indicated that mean basal SBP and DBP were significantly higher in obese subjects. It can be hypothesized that higher resting blood pressure in obese group could be due to higher vasoconstrictor tone and increase in cardiac output due to increased circulatory load on heart, as a consequence of increase in BMI body mass index.[20]

In our study comparison of parasympathetic tests between different groups according to BMI i.e. underweight, normal weight, overweight and obese were not statistically significant ($P > 0.05$). No change in parasympathetic nervous system functioning was found in obese children as compared to normal weight. This was also reported by Bedi et al[21] in "Assessment of Autonomic Function Activity in Obese Children" (2009) and also by Piccirillo et al[22] and Hofmann et al.[23] On inter group comparison of parasympathetic tests between normal weight vs overweight and normal weight vs obese subjects it revealed that there is no significant change in parasympathetic activity with an increase in BMI.

The mean resting SBP and DBP was highest for obese than for overweight than normal weight and under weight. However, on comparison of different groups the mean SBP and DBP difference HGT was found to be lower in obese than normal weight and was statistically significant ($P < 0.05$). Akhtar et al[24] who, studied sympathetic nerve function status in obesity (2010), also revealed mean values of resting SBP and DBP were significantly higher and blood pressure response to HGT was significantly lower in obese as compared to non obese control, indicating impaired sympathetic autonomic function. Bedi et al[21] also in HGT found that the DBP increase was less in obese children than that of controls indicating sympathetic insufficiency in obese children.

Another test of sympathetic function (CPT) revealed, that mean resting SBP and DBP was highest for obese than for overweight than normal weight and under weight. However, on comparison of different groups, the mean SBP and DBP difference CPT was found to be lower in obese than normal weight and was statistically significant ($P < 0.05$). On inter group comparison of sympathetic tests between normal weight vs obese subjects, results indicated that in obese subjects had increased sympathetic activity at the resting condition and blood pressure response to CPT was significantly lower in obese as compared to normal weight subjects, thus points towards sympathetic insufficiency in obese subjects. Similar results were found in the study by Bedi et al[21] and LeBlanc et al.[25] Valensi et al[26] also found sympathetic insufficiency was also associated with obesity. They showed that glucose-induced inhibition of the lipid oxidation rate in obese women was greater in the patients with autonomic dysfunction. This could be because of a decrease in sympathetic activity.

Landsberg et al[27] suggested that decreased sympathetic activity may result in a disordered homeostatic mechanism thus promoting excessive storage of energy.

The main goal of our study was to assess changes in sympathetic and parasympathetic nervous system activity in obese young adults. No change in parasympathetic nervous system functioning was found but there was an impaired sympathetic autonomic function in obese young adults as opposed to normal weight.

CONCLUSION

In conclusion, our study revealed an impaired sympathetic autonomic function in obese young adults as opposed to normal weight. Obesity is associated with ANS dysfunction which may because of various cardiovascular complications. So, if autonomic nervous system dysfunction is diagnosed early by doing autonomic function tests, it may prove an important aid in the identification of those prone to weight gain and are at higher risk of cardiovascular complications Thus, the exercise training in obese individuals may result not only in weight loss and reduction in cardiovascular risk but also in the improvement of the autonomic nervous system of thermoregulatory control over the obesity.[28]

Limitations of the study

The sample size in the present study is moderate, especially the sample was drawn from one limited geographical area, which is inadequate for extrapolating the application of these findings to the general population.

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