Effect of obesity on autonomic functions of Heart among healthy volunteers at a teaching Institute

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ABSTRACT

Background: Obesity usually results from an imbalance between energy intake and energy expenditure, that is, energy homeostasis, which is controlled by the autonomic nervous system. This imbalance results from multifaceted interactions of genetic, physiological, behavioral, environmental, endocrine, nervous, metabolic factors, which lead to hemodynamic and metabolic alteration.

Objective: To study the effect of obesity on the autonomic functions of the heart.

Methods: An observational analytical study was carried out among 100 subjects. All healthy volunteers of 30–50 years were included. The subjects were grouped into two categories of body mass index (BMI): 30–39.99 kg/m² as Obese group and BMI: 18.50–24.99 kg/m² as Non -Obese group. Out of 100 subjects, 50 were obese and 50 were non-obese. The interview was taken. General physical examination and anthropometric measurements were recorded. The assessment of various cardiac autonomic function tests was carried out. Results: Both groups were comparable for age and sex (P = 0.754). The resting heart rate, SBP, and DBP in the obese group were significantly higher compared to the non-obese group (P < 0.05). All values of autonomic function tests in the non-obese group were significantly higher compared to the obese group (P < 0.05) except for the Standing to lying ratio (P > 0.05). The values of SBP and DBP increased significantly in the non-obese people after the isometric handgrip test and cold press test compared to the obese people (P < 0.05). Conclusion: We conclude that the resting HR, SBP, and DBP were higher in obese people. However, after applying autonomic function tests, non-obese people respond better to these tests compared to obese people in the form of an increase in these parameters. Obesity is, thus, found to affect the autonomic function tests.

Keywords: Autonomic functions, effect, heart rate, obesity, overweight

Introduction

Obesity is a condition in which excess body fat accumulates to the extent that it may have an adverse effect on health leading to reduced life expectancy and increased health problems.⁹

Although obesity represents an unhealthy excess in body fat mass, the current practical definition of obesity is determined by an assessment of the body mass index (BMI). BMI is calculated by Quetelet’s Index (weight/height in meter squared). Men and women with a BMI between 18.5 and 24.9 kg/m² are considered to be normal weight. Those with a BMI between 25.0 and 29.9 kg/m² are considered to be overweight and those with a BMI greater than 30.0 kg/m² are considered to be obese.⁹

Overweight and obesity are the fifth leading risk of global deaths. Worldwide, obesity has more than doubled since 1980. In 2016, more than 1.9 billion adults, 18 years and older, were overweight. Of these, over 650 million men and women were obese.⁹

At least 3.4 million adults die each year as a result of being overweight or obese. In addition, 44% of the diabetes...
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**In India, 1.3% of males and 2.5% of females aged more than 20 years were obese in the year 2008.**

Obesity is a key risk factor in the natural history of other chronic and non-communicable diseases. The first adverse effects of obesity to emerge in the population in transition are hypertension, hyperlipidemia, and glucose intolerance, while coronary heart disease and the long-term complications of diabetes, such as renal failure, begin to emerge several years later.

Obesity usually results from an imbalance between energy intake and energy expenditure, that is, energy homeostasis, which is controlled by the autonomic nervous system (ANS). This imbalance results from multifaceted interactions of genetic, physiological, behavioral, environmental, endocrine, nervous, metabolic factors, which lead to hemodynamic and metabolic alteration.

Several studies in the literature suggest that the ANS of obese individuals is chronically altered. Since ANS is involved in energy metabolism and regulation of the cardiovascular system, an alteration in ANS can be strongly implicated in the development of obesity and pathophysiology of various cardiac complications.

The determination of obesity is quite simple with the help of Quetelet’s Index (weight/height²) and determining the autonomic status of each individual was made possible by non-invasive autonomic function tests such as standing test, standing to lying test, deep breath test, Valsalva test, handgrip test, etc.

Since there is a dearth of literature for comprehension studies concerning autonomic disturbances in obesity in India, especially Chhattisgarh, the present study has been attempted to assess the relationship between cardiac autonomic function and obesity in adults using autonomic function tests as diagnostic tools. The results of these tests would warn the person of the impending morbidities at an early stage so that one could take measures to reverse the state of obesity.

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**Material and Methods**

**Ethical standards**

Institution Ethics Committee permission was obtained before the start of the study. Informed consent was taken from all eligible participants.

**Study type**

The present study was an observational analytical type study and carried out in the Department of Physiology, Lt. BRKM Government Medical College, Jagdalpur, Chhattisgarh. The type of sampling adopted for this study is purposive sampling.

**Duration of the study**

The study was conducted over 21 months starting from December 2017 to August 2019.

**Sample size**

Hundred subjects.

**Study subjects**

All healthy volunteers within the age group of 30–50 years were included in the study. Based on BMI, the subjects were grouped into two categories as follows:

1. BMI - 30–39.99 kg/m²: Obese Group
2. BMI - 18.50–24.99 kg/m²: Non-Obese Group

The number of study subjects comprised 100 subjects, out of which obese were 50 and non-obese were 50 subjects. The healthy subjects of both groups were recruited based on the inclusion and exclusion criteria.

**Inclusion criteria**

1. Subjects in the age group 30–50 years of either gender.
2. Subjects with a BMI of 30–39.99 kg/m².
3. Subjects with a BMI of 18.50–24.99 kg/m².

**Exclusion criteria**

- Subjects suffering from any clinical diseases likely to affect ANS.
- Patients of malignant hypertension, diabetes, psychological diseases, head trauma, cardiac anomalies, Ischemic Heart Disease (IHD), cardiac failure, chronic obstructive lung diseases, psychological disorder, etc.
- Subjects taking medication, for example, vasodilators, α blockers, β blockers, barbiturates, opiates, Tricyclic antidepressants (TCA), and phenothiazine that could affect autonomic functions.
- Subjects with a history of smoking/alcohol/drug abuse.

The schedule for data collection for the study was prepared as per the objectives of the study after reviewing relevant literature.
Major components of the schedule
The schedule for data collection can broadly be categorized into three parts.
Part-I: Interview with the subject and informed consent.
Part —II: General physical examination and anthropometric measurement.
Part —III: Assessment of the various cardiac autonomic function tests.

Part-I: Interview with the subject. The subjects were asked if they had any history of the present or past illness. The subjects were then explained about the study, its objectives, and the procedure that they would take part in. This helped them stay calm and free from anxiety. Then, informed consent was taken from the subjects. It was, then, followed by a general examination of the subjects.

Part—II: General physical examination and anthropometric measurements were done. The age, height, weight, resting blood pressure, and resting heart rate were recorded. The BMI of all healthy subjects was calculated by the formula: BMI = weight (kg)/height (m)² [Quetelet’s Index]. The obesity status was assessed by using the BMI.[3]

All the subjects were examined for pallor, icterus, goiter, clubbing, lymphadenopathy, and pedal edema. The hair, eyes, ears, teeth and gums, oral cavity, and skin were examined. Systemic examinations were also done in all subjects.

Part III: Assessment of the various cardiac autonomic function tests. After the general physical examination of the subjects, cardiac autonomic function tests were conducted on the subjects to evaluate the integrity of the ANS in both groups. The cardiac autonomic function tests employed were in this order: Heart response on standing test (30:15 ratio), standing to lying (S/L) ratio, Valsalva ratio (VR), deep breathing test (DBT), isometric handgrip test (IHGT), and cold pressor test (CPT).[1]

Cardiac autonomic function tests
The cardiac autonomic function tests were performed with the help of an electrocardiograph, handgrip dynamometer, stethoscope, and sphygmomanometer. Before even the tests were initiated, the subjects were asked to rest for 15 min. Then, their resting heart rate and blood pressure were recorded. This was followed by the different autonomic function tests. The autonomic function tests are divided into two types:
1. Parasympathetic tests
2. Sympathetic tests

Following are the methods:

For assessing parasympathetic activity
1. Heart rate response to standing (30:15 ratio): The subject was asked to rise to erect posture from the supine position. The 30.15 ratio was calculated by taking the ratio of the longest R-R interval at beat 30 and the shortest R-R interval at beat 15 after standing.[15-17]

Heart response to standing (30:15 ratio)

| 30:15 ratio | Remarks          |
|------------|-----------------|
| > 1.3      | Normal          |
| 1 to 1.2   | Borderline      |
| < 1.0      | Autonomic insufficiency |

2. Standing to lying ratio (S/L ratio)
In this test, the subject was instructed to stand quietly, and then, lie down without any support while a continuous electrocardiogram (ECG) was recorded. The standing to lying ratio is calculated as the longest R-R interval during 5 beats before lying down to the shortest R-R interval during 10 beats in the ECG after lying down. The higher standing to lying ratios are seen in normal weighing persons while the lower standing to lying ratios are seen in autonomic deficient individuals.[15,16,19]

3. Heart rate response to Valsalva maneuver (VR)
The subjects were instructed to perform the Valsalva maneuver for 15 s by blowing through a mouthpiece attached to a manometer and maintained in an expiratory pressure of 40 mmHg for 15 s. The ECG was recorded during the maneuver and for 15 s after the release of pressure. The VR was calculated as the ratio of the longest R-R interval (after the release of strain) after the maneuver to the shortest R-R interval (during strain) during the maneuver.[15,16,19]

VR
< 1.1  Autonomic deficiency
1.2–1.44 Borderline
≥ 1.45 Normal

4. Heart rate response to DBT
The subjects were instructed to breathe deeply at the rate of six breaths per minute. A standard ECG recording was taken during deep inspiration and expiration. The variation in the heart rate was calculated as the rate of the longest R-R interval during expiration to the shortest R-R interval during inspiration.[15,16,20]

DBT
< 10 BPM Autonomic dysfunction
11–14 Borderline
≥ 15 Beats Per Minute (BPM) Normal

For assessing sympathetic activity
1. IHGT
After recording the basal blood pressure, the subjects were asked to perform isometric handgrip exercise with the help of a handgrip spring dynamometer. The subjects were asked to hold the handgrip spring dynamometer in the dominant hand to have a full grip on it. The handles of the dynamometer were compressed by the subject with maximum effort for a few seconds. The whole procedure was repeated thrice with rest in between to prevent fatigue. The
mean of the three readings was referred to as the maximal isometric tension (Tmax). Then, the subjects were asked to perform the isometric handgrip exercise at 30% of Tmax for 2 min. During the test, blood pressure was recorded from the non-exercising arm. The test result is presented as the difference between the highest diastolic pressure during the examination and the average diastolic pressure at rest.[15,16,21]

2. CPT

After recording the basal blood pressure, the subject was asked to dip the left arm in cold water (temp. 2–4°C) for 2 min and blood pressure was recorded from the right arm. A response of 15–20 mmHg increase in SBP and an increase of 10 mmHg in DBP is considered as a normal response to cold pressor test (CPT).[5,6,22]

Increase in BP due to CPT

| Increase in SBP | Remarks          |
|----------------|-----------------|
| 15–20 mmHg     | Normal response |
| <15 mmHg       | Abnormal        |

Increase in DBP

| ≥10 mmHg       | Normal response |
| <10 mmHg       | Abnormal        |

Statistical analysis

The data were entered in a Microsoft Excel worksheet. Mean and proportions were used to describe the data. Independent samples t-test was calculated to compare the difference of means in the two groups. The Chi-square test was used to compare the difference in the proportions of the two groups. A two-sided P value of less than 0.05 was taken as statistically significant.

Results

Both the groups were comparable for age and sex as seen from Table 1 (Chi-square = 0.397; P = 0.754) [Table 1].

The resting heart rate, SBP, and DBP in the obese group people were significantly higher compared to the non-obese group people (P < 0.05) [Table 2].

All the values of the autonomic function tests in the non-obese group were higher compared to the obese group. All these higher mean values were statistically significant for all ANS tests except for the S/L ratio [Table 3].

The values of the Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP) increased in the non-obese people after the IHGT and CPT compared to the obese people and all these were found to be statistically significant [Table 4].

### Table 1: Comparison of resting heart rate, SBP, and DBP in two groups

| Variables             | Category     | n  | Mean (mmHg) | Standard deviation | t     | P     |
|-----------------------|--------------|----|-------------|--------------------|-------|-------|
| Resting heart rate    | Obese        | 50 | 80.640      | 2.1069             | 5.026 | <0.001|
|                       | Non-obese    | 50 | 78.240      | 2.6385             |       |       |
| Resting SBP           | Obese        | 50 | 125.080     | 3.5042             |       |       |
|                       | Non-obese    | 50 | 118.320     | 4.1475             |       |       |
| Resting DBP           | Obese        | 50 | 82.560      | 3.2335             | 7.63  | <0.001|
|                       | Non-obese    | 50 | 78.400      | 2.0996             |       |       |

### Discussion

We found that both groups were comparable for age and sex (P = 0.754). Resting heart rate, SBP, and DBP in the obese group were significantly higher compared to the non-obese group (P < 0.05). All values of autonomic function tests in the non-obese group were significantly higher compared to the obese group (P < 0.05) except for the S/L ratio (P > 0.05). The values of SBP and DBP increased significantly in the non-obese people after the IHGT and CPT compared to the obese people (P < 0.05).

Adachi et al.[23] randomized 36 volunteers who were healthy and gave them a diet to increase their weight by 4 kg over 8 weeks followed by an 8-week loss of weight. They compared the heart rate variability at baseline, after gaining weight, and after losing weight. They found that the ratio of low frequency to high frequency increased after weight gain and became normal after weight loss compared to the control group. Similarly, there was an increase in the levels of adiponectin, leptin, and insulin after weight gain but became normal after weight loss. However, not all these were found to be correlated with the heart rate variability. The authors concluded that weight gain was associated with an increased cardiac sympathetic activation. However, they said that the exact mechanism was not clear.

Rodriguez-Colon et al.[24] found in their study that 12.3% of the children were obese. They compared the effect of BMI, percentiles of the height, percentiles of the weight, and waist circumference on the heart rate variability and found that weight was strongly correlated with the heart rate variability.

Oliveira et al.[25] studied the association between various factors with autonomic modulation of the cardiovascular system among
Table 3: Effect of obesity on the autonomic function tests

| Variables | Category | n  | Mean  | Standard deviation | t    | P    |
|-----------|----------|----|-------|--------------------|------|------|
| 30:15 ratio | Obese    | 50 | 0.9696 | 0.6931             | 29.373 | <0.001 |
|           | Non-obese | 50 | 1.4106 | 0.08042            |       |      |
| S/L ratio | Obese    | 50 | 1.0236 | 0.05264            | 1.103 | 0.273 |
|           | Non-obese | 50 | 3.9080 | 18.48485           |       |      |
| VR        | Obese    | 50 | 0.9922 | 0.09513            | 0.05632 | <0.001 |
|           | Non-obese | 50 | 1.6246 | 0.05632            |       |      |
| DBT (bpm) | Obese    | 50 | 9.220  | 1.2982             | 32.453 | <0.001 |
|           | Non-obese | 50 | 19.100 | 1.7173             |       |      |
| IHGT SBP (mmHg) | Obese | 50 | 134.320 | 3.2667             | 4.856 | <0.001 |
|           | Non-obese | 50 | 137.440 | 3.1569             |       |      |
| IHGT DBP (mmHg) | Obese | 50 | 90.960 | 3.2132             | 9.971 | <0.001 |
|           | Non-obese | 50 | 96.240 | 1.9226             |       |      |
| CPT SBP (mmHg) | Obese | 50 | 134.280 | 3.8121             | 3.475 | 0.001 |
|           | Non-obese | 50 | 136.800 | 3.4286             |       |      |
| CPT DBP (mmHg) | Obese | 50 | 90.080 | 2.9405             | 3.538 | 0.001 |
|           | Non-obese | 50 | 91.960 | 2.3383             |       |      |

64 obese patients. Sympathetic autonomic modulation was more in obese cases. They noted a negative association between high frequency and evaluation model. They also reported a negative association between the sympathetic component and moderate to vigorous physical activity. High frequency was found to be negatively associated with waist circumference and Homeostasis Model Assessment - Estimated Insulin Resistance (HOMA-IR) values. They concluded that cardiac autonomic modulation in obese cases was greatly influenced by central obesity and insulin resistance.

Indumathy et al. noted that the markers of sympathovagal imbalance (SVI) were more in obese people compared to non-obese people. The obese people exhibited reduced parasympathetic activity and increased sympathetic activities. The markers of SVI were correlated with the lipid risk factors, high sensitivity C reactive protein (hsCRP), HOMA-IR, and anthropometric indices.

Yadav et al. observed that the mean heart rate was significantly increased in obese people but the heart rate variability indicators were less. There was a significant positive correlation between low frequency and waist-hip ratio. It was negatively correlated with high-frequency power. The correlation between the BMI and heart rate variability was not statistically significant.

Goulopoulou et al. studied the effect of exercise on the vagal and sympathetic influences. Glucose ingestion was significantly associated with low-frequency heart rate variability and it decreased the high-frequency power. They concluded that regular exercise improves cardiac autonomic modulation.

Rossi et al. found that obese patients had a significantly low heart rate response on deep breathing compared to non-obese. They also had a significantly low heart rate response to the cross-correlation test compared to non-obese.

Quilliot et al. noted that the obese and overweight individuals exhibited significantly lower compared to their controls variability of normalized low-frequency (LF) spectral analysis of both HR and BP. There was a negative correlation between the BMI and normalized LF spectral analysis when controlled for age.

This study highlights that obesity hampers the autonomic functions of the individual and makes them prone to the development of cardiovascular diseases. Hence, it is important to prevent overweight and obesity.

### Conclusion

We conclude that the resting HR, SBP, and DBP were higher in obese people. However, after applying the autonomic function tests, non-obese people respond better to these tests compared to obese people in the form of an increase in these parameters. Obesity is, thus, found to affect the autonomic function tests.

Hence, primary prevention of obesity is important to prevent its adverse health effects. Health education and general awareness for the public are important to change their lifestyle to prevent obesity.

### Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

### Public health importance

This study highlights the fact that obesity hampers the autonomic functions of an individual and makes them prone to the development of cardiovascular diseases. Hence, it is important to prevent overweight and obesity.

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Nil.

### Conflicts of interest

There are no conflicts of interest.
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