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Original Article

Comparison of Cardiovascular Parameters and Cardiac Autonomic Activity of Obese and Normal Weight School Children in Puducherry

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Abstract

Background and Aim: Worldwide, incidence of childhood obesity is on the rising trend and obese children are more vulnerable to various health disorders. This study was done to assess and compare the cardiovascular parameters and Heart rate variability (HRV) parameters of obese school children with children with normal Body Mass Index (BMI).

Methods: Thirty obese children (BMI $\geq 95^{th}$ percentile) aged 9-12 years and 30 age and sex matched children with normal BMI (BMI 5^{th} to below 85^{th} percentile) were included in test and control groups respectively. Mann Whitney U test was done to detect the difference between the two groups with respect to systolic blood pressure (SBP), diastolic blood pressure (DBP) and HRV parameters. Sub-analyses were also done to compare the data of boys of control and test groups and the data of girls of control and test groups.

Results: SBP, DBP and Mean arterial pressure (MAP) were significantly high in the test group. However, there was no significant difference between test and control groups with respect to HRV parameters. Sub-analyses revealed that the obese boys had a significantly high SBP, DBP, MAP, rate pressure product (RPP) and a significantly low total HRV while the obese girls had a significantly raised SDNN, RMSSD, pNN50, LF power, HF power and total HRV.

Conclusion: The obese children had a significantly raised blood pressure. There was no difference in the HRV parameters of normal weight and obese children. However, obese boys had a significantly reduced total HRV when compared to normal weight boys while the obese girls had a significantly raised total HRV when compared to normal weight girls. The various physiological changes during puberty and the time of onset of puberty may have a varying impact on the cardiac autonomic status of obese male and female children.

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Introduction

Obesity is emerging as a major health concern both in the developed and developing countries, due to increase in the standard of living, sedentary lifestyle and unhealthy dietary patterns. In India, over the past 2-3 decades, there has been a drastic increase in the prevalence of obesity and overweight in the general population, and nearly 5% of the population is found to be obese (1). Studies on Indian children have also shown an increasing trend towards overweight and obesity (2). Obesity in childhood predisposes to obesity in adult life, growth and puberty disorders, cardiopulmonary disorders and various abnormalities in insulin, glucose and lipid metabolism (3).

The autonomic nervous system plays a major role in regulating the balance between energy intake and energy expenditure, which when disturbed, results in obesity (4). While there are several methods to assess the autonomic status of the individuals, Heart rate variability (HRV), also known as R-R interval variability is currently widely used as a noninvasive marker of the cardiac autonomic activity in various clinical scenarios (5, 6).

Studies on cardiac autonomic status of the obese pediatric population have revealed varying results. While some studies have reported a reduced sympathetic and parasympathetic activity among the obese children (7-10), there are studies which have reported an increased sympathetic and decreased parasympathetic activity (11-14) among these children. However, knowledge regarding the autonomic status of obese Indian children is limited. Similarly, gender based differences in the HRV parameters of obese and normal weight children are yet to be explored.

Hence, the aim of this study was to assess and compare the cardiovascular parameters (systolic blood pressure, diastolic blood pressure, mean arterial pressure, rate pressure product) and short-term HRV indices (time domain and frequency domain indices indicative of cardiac sympathetic and parasympathetic activity) of obese children and children with normal body mass index (BMI). In addition, comparison of the above said parameters were done among the obese boys and normal weight boys and the obese girls and normal weight girls.

Methods

Sixty school children aged 9-12 years studying in schools located in and around Puducherry were included in the study. The study was prior reviewed and approved by the Institutional Review Board and Ethical Committee. A written informed consent was obtained from the study participants and their parents and the study procedures were explained in detail to all the participants. Children with known history of chronic or acute medical illnesses, anxious and uncooperative children and those whose parents refused to give consent were excluded from the study.

Assessment of Body Mass Index (BMI):

Following standardized procedures, weight (nearest 0.5 kg) of the subjects was measured using a weighing (bathroom) scale and the height (nearest 0.1 cm) using a stadiometer. BMI was calculated using the formula, weight (kg) / height^2 (m). Age and sex-specific percentiles of BMI were followed to categorize the study participants into the test group which included children with BMI at or above the 95th percentile (obese) or into the control group which included children with BMI from 5th to below 85th percentile (normal) (15). Thirty students (15 boys and 15 girls) each were recruited in the test and control groups.

Recording of Blood pressure:

The participants were made to rest in supine posture for 15 minutes following which their ECG was recorded for Heart rate variability analysis. Hence, during this resting period, blood pressure was measured in the right arm with a manual sphygmomanometer using the appropriate cuff size. According to American Heart Association Scientific Statement**,** it is recommended that “minimum of two readings be taken, with atleast one-minute interval between them, and the average of the measurements recorded. It is also mentioned that, ideally, 5 minutes should elapse before the first reading is taken” (16).

In the current study, since the participants were school children, the first blood pressure (BP) reading was taken after 10 minutes of rest to aid in reducing the anxiety among the participants. After an interval of 5 minutes, the second BP reading was taken and the average of the first and second reading was taken as the BP of the subject. The above procedure was followed uniformly for the participants of the test and control group.

Mean arterial pressure (MAP) was calculated using the formula,

MAP= DBP+1/3PP (DBP- Diastolic blood pressure, PP- Pulse pressure, the difference of Systolic and Diastolic Blood Pressure)

Rate Pressure Product, (RPP), an indirect measure of myocardial workload and oxygen consumption was calculated using the formula, RPP = systolic pressure × heart rate × 10^{-2} (17).

Recording of Short-term Heart Rate Variability (HRV):

A five minute ECG in lead II configuration was recorded in the study participants using the "INCO Digital Physiograph" HRV Apparatus at a sampling rate of 1024 samples per sec. All recordings were done between 9-11 am in a light and noise minimized room in the school and a room temperature of 25°-27°C was maintained for all the recordings.

Heart rate variability (HRV) analysis:

The R-R intervals from the ECG data were screened for ectopic beats and noise and were analyzed as per the Guidelines of the Task force of the European society of Cardiology and the North American Society of Pacing and Electrophysiology (18). NEVROKARD aHRV ver. 12.0.0. (Medistar Inc., Slovenia) HRV analysis software was used to obtain the short-term HRV parameters indicative of cardiac sympathetic and parasympathetic activity.

Time domain parameters which were included in the analysis were (a) SDNN- Standard deviation of all normal to normal (NN) R-R intervals- measure of total Heart rate variability (b) RMSSD – The square root of the mean of the sum of the squares of differences between adjacent NN intervals - measure of parasympathetic activity and (c) pNN50 – percentage of number of pairs of adjacent NN intervals differing by more than 50 ms in the entire recording divided by the total number of all NN intervals - measure of parasympathetic activity.

Among the frequency domain parameters, the following were included in the study: (a) Low frequency (LF) power – obtained by integrating the power spectral density between 0.04–0.15 Hz- indicates sympathetic and parasympathetic activity (b) High frequency (HF) power – obtained by integrating the power spectral density between 0.15–0.4 Hz- indicates parasympathetic activity (c) LF normalized units (LF nu) obtained by dividing LF power by the sum of LF and HF power (Total power-VLF= LF+ HF)- indicates sympathetic activity (d) HF normalized units (HF nu) obtained by dividing HF power by the sum of LF and HF power (Total power-VLF = LF+ HF) - indicates parasympathetic activity (e) LF+HF - sum of LF power and HF power-indicates total heart rate variability (f) LF/HF obtained by dividing the LF power by the HF power-indicates sympatho-vagal balance.

Variables included in the study:

i. Anthropometric variables-height, weight,

ii. BMI

iii. Cardiovascular (CV) parameters – systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), rate pressure product (RPP)

iv. Short-term HRV parameters

   a. Time domain parameters (Mean RR, SDNN, RMSSD, pNN50)

   b. Frequency domain parameters (LF power, HF power, LF nu, HF nu, LF+HF, LF/HF)

Statistical Analysis:

Statistical analysis was done using SPSS 16 (SPSS Software Inc., Chicago, IL, USA). The study variables are presented as median with inter-quartile ranges. Mann Whitney U test was done to compare the variables of the control and test groups. Similar analyses were done to compare the study variables between the boys of the test and control groups and among the girls of the test and control groups. P values less than 0.05 was considered to be statistically significant.

Results

Thirty children with normal BMI (11.7±0.54 years, mean±SD) and 30 obese children (11.8±0.44 years, mean±SD) were recruited in the study. Children with normal BMI were included in the control group and obese children were included in the test group. There was no significant difference in age (P=0.142) between the subjects of the control group and test groups. The SBP, DBP and MAP of the test group subjects were significantly more (p<0.05) compared to that of control group subjects. However, there was no significant difference between the two groups with respect to the HRV parameters (Table I).

Comparison of data of boys in the control and obese group revealed a significantly high SBP, DBP, MAP and RPP and a significantly lower total HRV among the obese boys (Table II).

Comparison of data of girls in the obese (n=15) and control group (n=15) did not reveal any significant difference between the two groups with respect to the cardiovascular parameters. However, RMSSD, pNN50, SDNN, LF power, HF power and LF+HF were significantly more among the obese girls (Table III).

TABLE I : Comparison of body mass index (BMI), cardiovascular (CV) parameters, time domain indices (TDI) and frequency domain indices (FDI) of heart rate variability (HRV) analysis between normal weight children (control group) and obese children (test group).

Parameters	*Control group (n=30) Median (IQR)*	*Test group (n=30) Median (IQR)*	*P value*
BMI (kg/m^2)	18.44 (17.03-20.23)	25.33 (24.42-26.23)	<0.001
CV Parameters			
SBP (mmHg)	120 (111.50-126.50)	121 (120-140.50)	0.012
DBP (mmHg)	79 (76-82.50)	90 (80-97)	<0.001
MAP (mmHg)	92 (88.67-96.83)	100 (93.33-109.83)	<0.001
RPP	95.03 (86.30-103.71)	104.27 (91.97-117.26)	0.084
TDI of HRV			
Mean RR (ms)	741.31 (683.22-856.02)	745.25 (672.11-826.45)	0.988
RMSSD (ms)	42.18 (28.46-75.47)	49.45 (33.20-80.90)	0.506
pNN50 (%)	23.73 (6.67-45.10)	22.55 (12.25-45.29)	0.469
SDNN (ms)	45.03 (32.22-72.77)	50.94 (40.34-68.99)	0.425
FDI of HRV			
LF Power (ms^2)	836.12 (487.29-2376.45)	1355.40 (671.37-2476.59)	0.315
HF Power (ms^2)	1421.41 (479.41-4082.37)	1622.58 (565.99-3770.62)	0.929
LF nu	0.40 (0.29-0.51)	0.41 (0.30-0.69)	0.315
HF nu	0.60 (0.49-0.71)	0.59 (0.31-0.70)	0.315
LF + HF (ms^2)	2482.76 (1054.59-6805.90)	3550.40 (1347.07-6284.38)	0.723
LF/HF	0.67 (0.40-1.06)	0.71 (0.43-2.27)	0.315

Values are expressed as Median (IQR-Inter-quartile range). Mann Whitney U test- p value.

BMI = body mass index; BHR = basal heart rate; SBP = systolic blood pressure; DBP = diastolic blood pressure; MAP = mean arterial pressure; RPP = rate pressure product; Mean R-R= mean duration of R-R interval; RMSSD = square root of the mean of the sum of the squares of differences between adjacent NN intervals; pNN50= percentage of NN50 count divided by the total number of all NN intervals; SDNN = standard deviation of normal-to-normal intervals; LF power = low frequency power; HF power = high frequency power; LF nu = low frequency power, normalized units; HF nu = high frequency power, normalized units; LF+ HF = sum of LF and HF power; LF/HF = ratio of low to high frequency power.

TABLE II : Comparison of body mass index (BMI), cardiovascular (CV) parameters, time domain indices (FDI) and frequency domain indices (TDI) of heart rate variability (HRV) analysis between normal weight boys and obese boys.

Parameters	*Normal weight boys (n=15) Median (IQR)*	*Obese boys (n=15) Median (IQR)*	*P value*
BMI (kg/m^2)	18.86 (17.36-20.20)	25.11 (24.22-26.74)	<0.001
CV Parameters			
SBP (mmHg)	118 (110-126)	140 (130-150)	<0.001
DBP (mmHg)	80 (78-80)	96 (90-100)	<0.001
MAP (mmHg)	92.67 (90.00-96.00)	108.67 (103.33-116.67)	<0.001
RPP	87.92 (81.24-95.00)	106.71 (92.61-127.23)	0.002
TDI of HRV			
Mean RR (ms)	853.49 (744.80-886.21)	759.76 (679.27-894.91)	0.233
RMSSD (ms)	70.15 (46.94-101.95)	46.44 (37.97-91.32)	0.137
pNN50 (%)	44.31 (30.20-62.75)	22.35 (19.22-58.04)	0.233
SDNN (ms)	71.79 (56.81-103.23)	49.05 (41.03-72.55)	0.098
FDI of HRV			
LF Power (ms^2)	2351.71 (767.12-3583.72)	965.37 (541.93-1508.84)	0.081
HF Power (ms^2)	3870.84 (2319.05-12838.88)	1567.72 (386.38-4973.14)	0.050
LF nu	0.34 (0.21-0.50)	0.35 (0.29-0.71)	0.389
HF nu	0.66 (0.50-0.79)	0.65 (0.29-0.71)	0.389
LF + HF (ms^2)	6670.82 (4537.88-17296.25)	1983.01 (1143.50-7091.49)	0.045
LF/HF	0.51 (0.26-1.00)	0.55 (0.41-2.50)	0.389

Values are expressed as Median (IQR-Inter-quartile range). Mann Whitney U test - p value.
BMI = body mass index; BHR = basal heart rate;; SBP = systolic blood pressure; DBP = diastolic blood pressure; MAP = mean arterial pressure; RPP = rate pressure product; Mean R-R= mean duration of R-R interval; RMSSD = square root of the mean of the sum of the squares of differences between adjacent NN intervals; pNN50= percentage of NN50 count divided by the total number of all NN intervals; SDNN = standard deviation of normal-to-normal intervals; LF power = low frequency power; HF power = high frequency power; LF nu = low frequency power, normalized units; HF nu = high frequency power, normalized units; LF+ HF = sum of LF and HF power; LF/HF = ratio of low to high frequency power.

TABLE III : Comparison of body mass index (BMI), cardiovascular (CV) parameters, time domain indices (TDI) and frequency domain indices (FDI) of heart rate variability (HRV) analysis between normal weight girls and obese girls.

Parameters	*Normal weight girls (n=15) Median (IQR)*	*Obese girls (n=15) Median (IQR)*	*P value*
BMI (kg/m^2)	18.12 (15.82-20.33)	25.33 (24.99-25.51)	<0.001
CV Parameters			
SBP (mmHg)	120 (112-128)	120 (120-120)	0.744
DBP (mmHg)	78 (76-84)	80 (80-90)	0.081
MAP (mmHg)	92 (88.67-98.67)	94 (93.33-100)	0.148
RPP	103.65 (100.24-122.46)	100.51 (91.69-115.02)	0.267
TDI of HRV			
Mean RR (ms)	691.77 (627.16-718.15)	717.69 (626.00-806.24)	0.233
RMSSD (ms)	32.62 (21.96-36.84)	51.43 (32.99-70.98)	0.019
pNN50 (%)	10.59 (1.96-17.25)	28.63 (11.37-43.53)	0.016
SDNN (ms)	33.87 (30.15-43.87)	51.42 (38.27-68.94)	0.008
FDI of HRV			
LF Power (ms^2)	615.26 (328.40-836.12)	1812.56 (888.94-2633.40)	0.003
HF Power (ms^2)	774.37 (360.80-1411.11)	1677.45 (793.86-3553.99)	0.026
LF nu	0.44 (0.34-0.54)	0.47 (0.36-0.69)	0.683
HF nu	0.56 (0.46-0.66)	0.53 (0.31-0.64)	0.683
LF + HF (ms^2)	1196.92 (908.77-2128.82)	3948.63 (1679.55-6187.39)	0.007
LF/HF	0.79 (0.51-1.16)	0.87 (0.56-2.27)	0.683

Values are expressed as Median (IQR-Inter-quartile range). Mann Whitney U test- p value.
BMI = body mass index; BHR = basal heart rate;; SBP = systolic blood pressure; DBP = diastolic blood pressure; MAP = mean arterial pressure; RPP = rate pressure product; Mean R-R= mean duration of R-R interval; RMSSD = square root of the mean of the sum of the squares of differences between adjacent NN intervals; pNN50= percentage of NN50 count divided by the total number of all NN intervals; SDNN = standard deviation of normal-to-normal intervals; LF power = low frequency power; HF power = high frequency power; LF nu = low frequency power, normalized units; HF nu = high frequency power, normalized units; LF+ HF = sum of LF and HF power; LF/HF = ratio of low to high frequency power.

Discussion

In our study, we observed that the obese children had significantly raised systolic and diastolic blood pressure and mean arterial pressure when compared to children with normal BMI. Studies by Torrance et al. (19), and Martini et al. (14), have also reported high blood pressure values among the obese children. Previous studies on heart rate variability among obese children have reported conflicting results. Baum et al. (7), Vanderlei et al. (8), and Nagai et al. (9), have reported reduced sympathetic and parasympathetic activity in obese children. In 2003, a study by Nagai et al. (10), reported that the decreased sympathetic and parasympathetic activity in obese children was associated with the duration of obesity. Study by Yakinci et al. (20), has shown that the obese children had normal sympathetic activity and reduced parasympathetic activity. In contrast to the above mentioned findings, studies by Tascilar et al. (11), Kaufman et al. (12), Rabbia et al. (13), and Martini et al. (14), have reported an increased sympathetic and a reduced parasympathetic activity among the obese children. However, in our study, there was no significant difference between the obese and normal weight children with respect to HRV parameters and this could be due to the small sample size. To the best of our knowledge, gender based differences among the obese and normal weight children have not been reported in the previous literature (7-14, 19). Hence, to address this issue, a pair of sub-analysis was done in this study to compare the cardiovascular (CV) parameters, time domain indices (TDI) and frequency domain indices (FDI) of HRV among boys belonging to the control and test groups and among the girls belonging to the control and test groups. Since gender based distribution bias may also influence the results of the study, it was ensured that equal number of boys and girls were recruited in the test and control groups.

Comparison of data of boys in the control and test group revealed a significantly high SBP, DBP, MAP and RPP and a significantly low total HRV (LF+HF) among the obese boys. This may indicate a decreased cardiac autonomic activity and an increased sympathetic vasomotor tone in the obese boys. On the other hand, comparison of data of girls in the control and test group did not reveal any significant difference with respect to the CV parameters. However, HRV indices indicative of cardiac parasympathetic activity (RMSSD, pNN50 and HF power) and cardiac sympathetic activity (LF power) were significantly high among the obese girls. SDNN and LF+HF, measures of total heart rate variability were also significantly high among the obese girls. Thus, the cardiac autonomic activity seemed to be more among the obese girls.

The sub-analysis results showed that the obesity induced changes in the cardiovascular parameters and cardiac autonomic status were different in obese boys and obese girls when compared with their age matched controls. While the cardiac autonomic activity seemed to be decreased among the obese boys, the same was seen to be increased among the obese girls. These variations could be attributed to the following factors: (i) Gender- gender based differences in the various physiological parameters (21) (ii) Age factor- as the study participants were between 9-12 years of age which is usually considered as the age for onset of puberty, it is likely that the various hormonal changes and the alterations which occur in their body compositions could have led to the differences in their autonomic status (22,23) (iii) regional distribution of body fat (24).

A study by Gao et al. (24), on obese post menopausal females reported that individuals with combined upper body obesity and visceral obesity had higher cardiac sympathetic and parasympathetic activity when compared to individuals with lower body and subcutaneous obesity. Hence, it may be hypothesized that the female obese children in the pubertal age group may have an upper body pattern of fat distribution which could have led to their increased cardiac sympathetic and parasympathetic activity as seen in the HRV analysis of this study.

Leptin, the hormone secreted by the adipocytes, is considered as one of the major determinant for the onset of puberty (25, 26). It is produced in proportion to the body fat mass (27-29) and it plays a major role in regulating the balance between appetite and energy expenditure. Studies on Leptin have shown

that this hormone is also involved in the regulation of sympathetic tone and arterial blood pressure through its central and peripheral actions (30). It is also reported that in obesity, the high leptin concentration results in adverse effects on the cardiovascular system such as hypertension and atherosclerosis (31, 32). Hence, it may be hypothesized that the increased sympathetic activity and total heart rate variability observed among the obese girls could be due to the raised leptin levels in these individuals when compared to the girls with normal BMI. However, absence of similar changes in HRV among the obese boys could be due to the fact that the onset of puberty in boys is little later than the girls (23). Hence, follow-up studies are required to see if the cardiac autonomic changes observed in girls occur in boys and to see if these changes persist with advancing age.

Conclusion

Childhood obesity predisposes to alterations in the cardiovascular and cardiac autonomic status. Body mass index and the various physiological and hormonal changes that occur during puberty may have a differential impact on the cardiac autonomic status of male and female children.

Limitations

The small sample size could be a limitation to our study. Similarly, pubertal staging and leptin assay were not included in the study. Hence, the extent of correlation between the above said parameters and the alterations in the cardiac autonomic status of the children could not be studied.

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