Defence Life Science Journal, Vol. 4, No. 3, July 2019, pp. 175-181, DOI : 10.14429/dlsj.4.13732

Normal Body Mass Index and Heart Rate Variability

Jitendra Kumar Jain[#] and Ranjan Maheshwari[$,*]

[#]*Government Engineering College, Bikaner - 334 004, India*
[$]*Rajasthan Technical University, Kota - 324 010, India*
[*]*E-mail: jitendra.ecb@gmail.com*

ABSTRACT

The autonomic nervous system (ANS) works in synergy with the Endocrine system that affects the body-mass and height and in turn the body mass index (BMI). The ANS activities are often assessed with one index that is heart rate variability (HRV). Reduced HRV has been reported in underweight (low BMI) and overweight (high BMI) individuals, but there is scarce information available on the relationship between normal BMI and HRV. Further, as per WHO expert consultation report, the Asian population has higher percentage of body fat than their European counterparts, therefore Asian people may have greater risk factors for type 2 diabetes and cardiovascular disease even below the existing upper edge of normal BMI. Thus it was recommended by WHO to consider the intermediate cutoff points within the normal BMI range as 18.5 Kg/m^2, 20 Kg/m^2, 23 Kg/m^2, and 25 Kg/m^2 for the Asian population. Therefore, the present study was aimed to investigate ANS activity among intermediate cutoff points of normal BMI using HRV. Seventy young individuals participated in the non-invasive and benign study. Subjects were divided into three groups based on their BMI as per the recommendation of the WHO report; NB1 ($18.5<BMI\leq 20$), NB2 ($20<BMI<23$) and NB3 ($23<BMI<25$). For all the subjects, 10 min of electrocardiogram was recorded and short term HRV analysis was carried out. Student t test was carried out to find the significance of study parameters in BMI groups. The BMI was correlated with HRV measures using Spearman's correlation method. Statistically significant negative correlation was found between BMI and various HRV parameters. The sympathovagal balance was comparable in NB1 and NB2 group whereas it shifted towards sympathetic dominance in NB3 group. Higher sympathetic activity for BMI greater than 23 in Indian youth may lead to predictability of risks associated with overweight and obesity.

Keywords: Body mass index; Autonomic nervous system; Heart rate variability; Body weight, Sympathetic activity.

1. INTRODUCTION

Since ages, it is a notion that physical appearance and physical capabilities often depend upon the weight (mass) and size of the body. A ratio of the body mass (Kg) and square of the height (m^2) yields body mass index (BMI). BMI is a numerical figure that gives an idea of the physical type of the human body and its subgroups are often categorised qualitatively. A BMI of less than 18.5 is classified as underweight, from 18.5 to 25 as normal, between 25 and 30 as overweight and more than 30 is termed as obesity[1]. Hence, the BMI is an easy and noninvasive way to evaluate the degree of excess weight in adults[2]. As per epidemiological reports, the proportion of overweight and obese adults increased globally from 28.8 per cent in 1980 to 36.9 per cent in 2013 for men and from 29.8 per cent to 38 per cent for women[1]. Thus, prevalence of high BMI rapidly increased in last decades. To address this global issue, researchers have focused on the studies concerning obesity/overweight and its effects in developing the cardiovascular risks and other chronic diseases. Therefore, many research studies have demonstrated the association of BMI with increasing risk for cardiovascular diseases in overweight and obese subjects[3-5].

In addition to obese/overweight cases, studies on underweight/ low BMI subjects have also been reported with reduced autonomic cardiac function[6-7]. It may be attributed to increased visceral adiposity or ectopic fat rather than subcutaneous fat in low BMI individuals. Sowmya et al. stated that a slight increase in BMI among low BMI subjects, risk of cardiovascular morbidity and mortality could be increased[8]. In India due to various reasons changes are very rapid at present and nutritional transition is a major concern[9]. The increased rate of urbanisation and migration from rural to urban setup may change the food consumption pattern. The high caloric food intake and reduced physical activities resulted into shifting of low BMI individuals towards normal BMI, and later into higher BMI[10]. Therefore, transitional normal BMI individuals may be at higher risk of developing metabolic syndrome or cardiovascular disease or other chronic diseases. In WHO expert consultation report, it is stated that the Asian population has higher percentage of body fat than their European counterparts, therefore Asian people have greater risk factors for type 2 diabetes and cardiovascular disease even

Received : 16 October 2018, Revised : 8 April 2019
Accepted : 10 May 2019, Online published : 15 July 2019

below the existing edge of 25 Kg/m^2 for normal BMI. It is thus recommended to consider the intermediate cutoff points within the normal BMI range as 18.5 Kg/m^2, 20 Kg/m^2, 23 Kg/m^2, and 25 Kg/m^2 for the Asian population[11].

The autonomic nervous system (ANS), regulates a wide range of metabolic, cardiopulmonary and visceral functions[12]. The ANS works in synergy with endocrine system to control several processes related to the digestion and metabolism of nutrients[13]. Thus, ANS plays a vital role in weight regulation. Molfino et al. further stated that ANS regulate the body weight not only in obese subjects but also in healthy individuals[14]. The ANS activity may be assessed by heart rate variability (HRV), which is a noninvasive method used for healthy individuals as well as cardiovascular and non-cardiovascular disorders[15]. Therefore, HRV has been popularly used by many researchers in evaluating the effect of overweight and obesity in risk stratification of cardiovascular and many other chronic diseases[16-19]. A reduced HRV has been reported in these studies, which is an indicator of greater risk of cardiovascular morbidity and mortality caused by cardiac autonomic alterations.

A lack of literature was experienced by the authors exploring HRV at intermediate cut off points of normal BMI. Therefore, the present study was aimed to investigate the ANS activity among normal BMI subjects using HRV.

Table 1. Distribution of the study population

Parameters	Body Mass Index (Kg/m^2)		
	NB1 (18.5<BMI≤20)	NB2 (20<BMI≤23)	NB3 (23<BMI<25)
n	26	25	19
Age (Years)	20.23±1.73	21.08±1.75	22.8±2.59
Height (m)	1.69±0.08	1.70±0.10	1.75±0.12
Weight (Kg)	54.37±4.86	62±7.19	75±11.17
BMI (Kg m^{-2})	18.98±0.40	21.52±0.71	24.49±0.50
SBP (mmHg)	107.27±5.66	111.8±7.44	121.13±9.16
DBP (mmHg)	73.04±3.79	74.36±2.94	78.4±5.24

Values are shown as mean ± SD
NB1, normal body mass index 1; NB2, normal body mass index 2; NB3, normal body mass index 3; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure

Table 2. Mean HRV measures for the study population

Parameters	Body Mass Index (Kg/m^2)			p value	
	NB1 (18.5<BMI≤20)	NB2 (20<BMI≤23)	NB3 (23<BMI<25)	NB1 vs NB2	NB2 vs NB3
SDNN (ms)	59.99±19.91	49.32±15.20	45.37±21.37	<0.05*	0.317
RMSSD (ms)	66.38±28.64	54.48±22.15	44.45±32.62	<0.05*	0.236
pNN50 (%)	40.27±18.16	31.76±19.87	21.84±19.61	<0.0001*	0.073
LF (ms^2)	1718.62±1307.62	1123.24±798.97	1151.13±822.13	<0.05*	0.375
HF (ms^2)	1792.58±1653.94	1098.8±834.3	722±1336.97	<0.05*	0.316
LF (n.u.)	51.48±18.32	52.49±17.43	68.45±12.55	0.421	0.008*
HF (n.u.)	48.45±18.26	47.43±17.42	35.10±12.45	0.419	0.008*
TP (ms^2)	3622.62±2637.18	2311.6±1368.3	1990.47±2123.23	<0.05*	0.457
LF/HF	1.4±1.0	1.44±1.0	2.16±0.99	0.441	<0.05*

Values are shown as mean ± SD
Abbreviations: SDNN, standard deviation of NN intervals; RMSSD, root mean square of differences of successive RR intervals; pNN50, percentage of RR intervals greater than 50 ms; LF nu, Low frequency power in normalized units; HF nu, High frequency power in normalized units; TP, total power.

2. MATERIALS AND METHODS

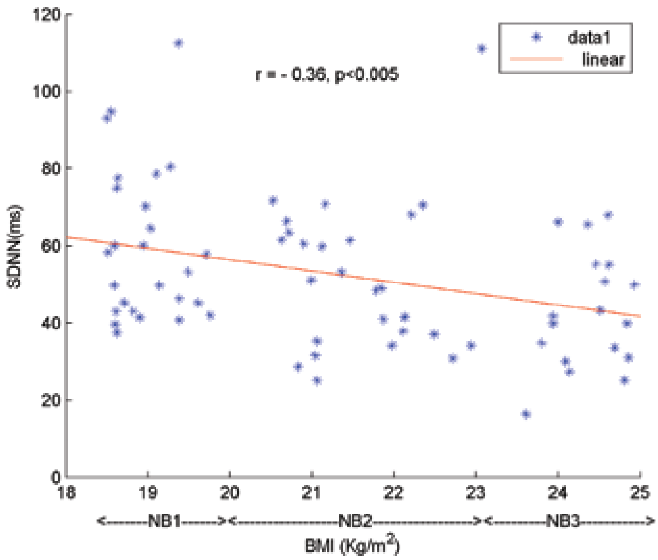
A number of adult graduating students and staff members were invited to take part in the study. The height and weight of each participant was measured. BMI was calculated as a ratio of weight to the square of height[20]. As per the World Health Organisation (WHO) criteria of BMI[1], normal range of BMI is defined from 18.5 to 25. Details of the study, procedure and objectives were explained to the subjects prior to the data acquisition and written consent was obtained. The consenting volunteers were examined for the following inclusion criteria:

- Systolic blood pressure <140 mmHg and diastolic blood pressure <90 mmHg.
- No history/treatment of any cardiovascular disease, diabetes or any other abnormality that would interfere with cardiac autonomic function as reported by individuals.
- BMI greater than 18.5 and less than 25.

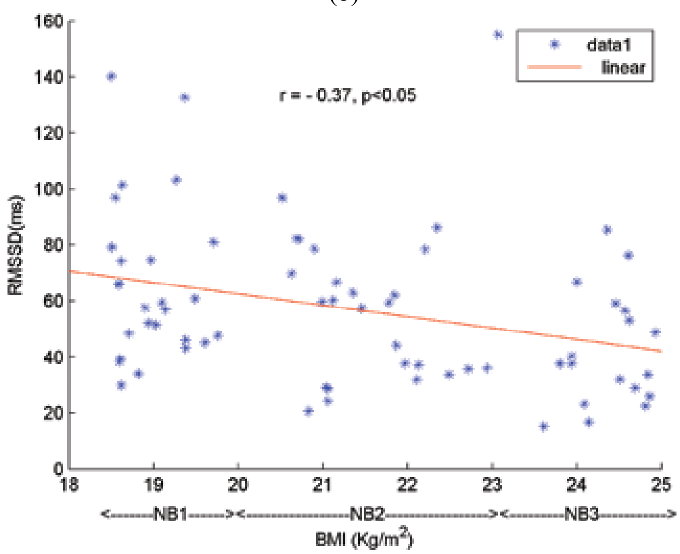
Based on these inclusion criteria, 70 young individuals with age ranging from 18 to 27 years were chosen to participate in this study. The study population was further divided into three categories, normal_BMI_1 (NB1) (18.5<BMI ≤20), normal_BMI_2 (NB2) (20<BMI≤23) and normal_BMI_3 (NB3) (23<BMI<25) with reference to the WHO expert consultation report[11]. The distribution of the study population is presented in Table 1.

The subjects were asked to sit in relaxed position for 15 min. Blood pressure was measured using Sphygmomanometer (MLT1100/A) and powerLab26®, after relaxing period. The ECG lead II was recorded in supine position with normal breathing for 10 minutes duration with a PowerLab26® data acquisition system.

(a)



(b)



(c)

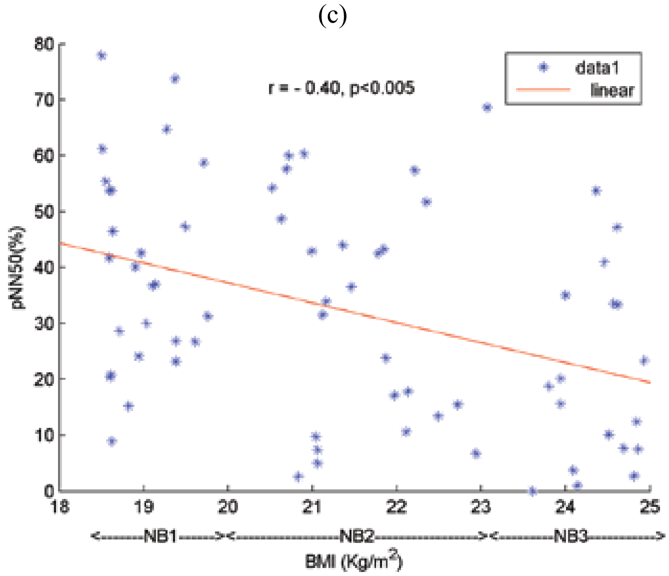


Figure 1. Variation of time domain HRV indices with BMI.

2.1 Data Processing

Out of the 10 minutes of ECG recording; smooth, noise free 5 minutes duration of ECG was selected for short term HRV analysis. The HRV module detected beats by detecting R waves in the ECG signal. The beats were classified as normal or ectopic beat based on preset limit. The ectopic beats were identified if the inter beat interval (IBI) differed more than ±30 per cent from the mean[21]. The cubic spline interpolation method was used to replace the ectopic beats with interpolated values based on weighted average of nearby accepted values. Thus, ectopic beats free RR interval was obtained which is termed as NN (normal to normal) intervals. The NN intervals were further normalised with average NN interval for HR bias minimisation[22]. Time domain HRV indices e.g. Standard Deviation of normal (SDNN) RR intervals, Root Mean Squared (RMSSD) differences of normal RR intervals, pNN50 count (number of adjacent RR intervals differ by more than 50 ms) were obtained from HRV module of the LabChart8.0® software[15]. Spectral components of HRV e.g. Low Frequency (LF) power, High Frequency (HF) power, Total Power (TP) and LF/HF ratio were obtained by a fast Fourier transformation technique[23].

The data was tested for normality by Kolmogorov-Smirnov test. Student t test (two tailed, independent) was carried out to find the significance of study parameters between NB1, NB2 and NB3 groups. Differences were considered significant at the level $p<0.05$. Spearman's rank correlation test was used to find out the correlation between BMI and HRV indices[24].

3. RESULTS

Descriptive physical characteristics of the study population are summarised in Table 1. All the subjects were having normal BMI. The normal BMI was stratified into three categories; NB1 (n=26; range 18.5<BMI≤20), NB2 (n=25; range 20<BMI≤23) and NB3 (n=19; range 23<BMI<25).

The time and frequency domain HRV indices were obtained with LabChart8.0® software. The average values of HRV measures for all the three normal BMI categories are as presented in Table 2.

A statistically significant difference was found in SDNN, RMSSD, pNN50, LF(ms^2), HF(ms^2) and TP values ($p<0.05$) between NB1 and NB2 group whereas LF(n.u.), HF(n.u.) and LF/HF values were statistically significant different ($p<0.05$) between NB2 and NB3 group. The SDNN, RMSSD and pNN50 values decreased with increasing of the BMI in the normal range. The LF(ms^2), HF (ms^2), HF(n.u.) and TP(ms^2) also decreased with increasing BMI in the normal range whereas the LF(n.u.) and LF/HF values increased with increasing the BMI.

The variation of the time domain HRV indices with BMI is as shown in Fig. 1. The scatter plot of the data is presented for the SDNN, RMSSD and pNN50. The negative slope of the linear approximation indicates the inverse relationship between HRV indices and BMI. The SDNN (r = -0.36, $p<0.005$), RMSSD (r = -0.37, $p<0.05$) and pNN50 (r = -0.40, $p<0.005$) correlated with BMI significantly. The HRV decreased with increasing BMI. The NB1 group had higher HRV than NB2 group with lowest HRV in the NB3 group.

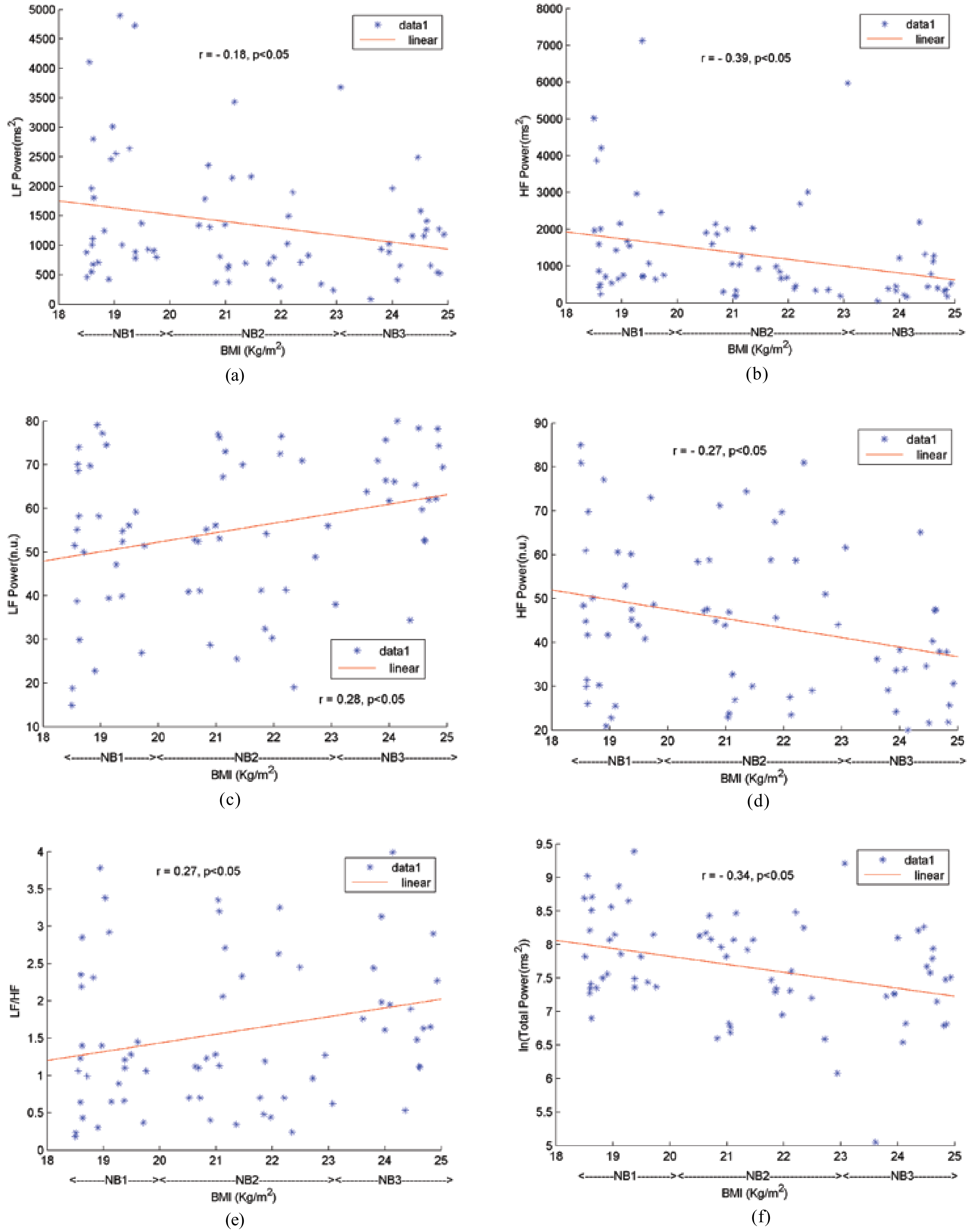


Figure 2. Variation of frequency domain HRV indices with BMI.

The variation of frequency domain HRV indices with BMI is shown in Fig. 2.

The LF(ms^2) (r = -0.18, $p<0.05$), HF(ms^2) (r = -0.39, $p<0.05$), HF(n.u.) (r = -0.27, $p<0.05$), and TP (r = -0.34, $p<0.05$) had negative statistically significant correlation with BMI whereas LF(n.u.) (r = 0.28, $p<0.05$) and LF/HF ratio (r= 0.27, $p<0.05$) had positive statistically significant correlation with BMI. The NB1 group also had higher values of frequency domain HRV indices than NB2 group whereas NB3 group had lowest HRV values. The spearman's rank correlation for HRV indices with BMI is presented in Table 3 for the entire normal BMI range. The BMI was found statistically significant with all mentioned HRV indices. The SDNN and pNN50 had strongest correlation ($p<0.005$) with BMI.

Table 3. Spearman's rank correlation between HRV parameters and BMI

HRV Parameters	BMI (r, p)
SDNN (ms)	-0.36, 0.0049**
RMSSD (ms)	-0.37, 0.0077*
pNN50 (%)	-0.40, 0.0008**
LF (ms^2)	-0.18, 0.0404*
HF (ms^2)	-0.39, 0.0111*
LF (n.u.)	0.28, 0.0200*
HF (n.u.)	-0.27, 0.0200*
TP (ms^2)	-0.34, 0.0104*
LF/HF	0.27, 0.0350*

*statistically significant at p<0.05, **statistically significant at p<0.005

4. DISCUSSION

The present study proposes evidences of association between BMI and HRV in normal BMI subjects too. The intermediate cutoff points of normal BMI were grouped as NB1, NB2 and NB3 as recommended by WHO consultation report. The overall ANS function assessed by SDNN and TP decreased significantly ($p<0.05$) in NB2 group as compared with NB1 group whereas sympathovagal balance as assessed by LF/HF ratio did not show significant variation. It signifies an overall reduction in the ANS function but not altered sympathovagal balance in the first two groups. An increase of L.F. (n.u.) ($p<0.05$) and decrease of H.F. (n.u.) ($p<0.05$) was found in NB3 group along with a shift in the sympathovagal balance towards sympathetic dominance ($p<0.05$). This suggests that sustained increased sympathetic activity may enhance vulnerability to cardiovascular disorders and other chronic diseases[25].

The Spearman's correlation was obtained between HRV indices and BMI for the entire normal BMI range (18.5-25). A statistically significant negative correlation ($p<0.05$) was found between BMI and SDNN, RMSSD, pNN50, LF(ms^2), HF(ms^2), HF(n.u.) and TP whereas positive significant correlation ($p<0.05$) was obtained between BMI and LF(n.u.) and LF/HF ratio. This indicates an increased sympathetic activity and decreased parasympathetic activity with increasing BMI in healthy normal BMI subjects. The results are in agreement with the studies reported by Arrone et al. and Krishna et al., who demonstrated significant weight gain with reduced parasympathetic activity in non-obese subjects while there was substantial weight loss with decreased sympathetic activity and increased parasympathetic activity[26,27]. Similarly, Koenig, J. et al. also presented the association of sympathovagal balance to BMI in non-obese healthy individuals[28]. They reported a prominent role of vagal nerve in modulation of the energy expenditure in the human organism.

5. CONCLUSIONS

This study proposes that body mass index (BMI) is related to the autonomic nervous system (ANS) activity in normal BMI individuals too. The sympathovagal balance is in homeostasis in lower range of normal BMI (NB1 and NB2) whereas, it shifted towards sympathetic dominance in the upper range of normal BMI (NB3). It would be appropriate if early interventional activities like physical exercise, yoga, meditation and healthy food habits are resorted to reduce weight for better ANS activities in Indian youth with BMI exceeding 23. This may help prevent tendencies towards obesity.

REFERENCES

1. Mehrabani, J. & Ganjifar, Z.K. Overweight and obesity: A brief challenge on prevalence, complications and physical activity among men and women. *MOJ Women's Health*, 2018, **7**(1), 19-24. doi: 10.15406/mojwh.2018.06.00161.
2. Subramaniam, B.S. Influence of body mass index on heart rate variability (HRV) in evaluating cardiac function in adolescents of a selected Indian population. *Ital. J. Public Health*, 2011, **8**(2), 149-55. doi: 10.2427/5657.
3. Flint, A.J.; Rexrode, K.M.; Hu, F.B.; Glynn, R.J.; Caspard, H.; Manson, J.E.; Willett, W.C. & Rimm, E.B. Body mass index, waist circumference and coronary heart disease: A prospective study among men and women. *Obes. Res. Clin. Pract.,* 2010, **4**(3), e171-81. doi: 10.1016/j.orcp.2010.01.001.
4. Fang, J.; Wylie-Rosett, J.; Cohen, H.W.; Kaplan, R.C. & Alderman, M.H. Exercise, body mass index, caloric intake and cardiovascular mortality. *Am. J. Prev. Med.,* 2003, **25**(4), 283-9. doi: 10.1016/S0749-3797(03)00207-1.
5. Wei, M.; Kampert, J.B.; Barlow, C.E.; Nichaman, M.Z.; Gibbons, L.W.; Paffenbarger, R.S. Jr. & Blair, S.N. Relationship between low cardiorespiratory fitness and mortality in normal-weight, overweight and obese men. *JAMA*, 1999, **282**(16), 1547-53. doi: 10.1001/jama.282.16.1547.
6. Triggiani, A.I.; Valenzano, A.; Ciliberti, M.A.; Moscatelli, F.; Villani, S.; Monda, M.; Messina, G.; Federici, A.; Babiloni, C. & Cibelli, G. Heart rate variability is reduced

in underweight and overweight healthy adult women. *Clin. Physiol. Funct. Imaging,* 2015, **37**(2), 162-7. doi: 10.1111/cpf.12281.
7. Vaz, M.; Bharathi, A.V.; Sucharita, S. & Nazareth, D. Heart rate variability and baroreflex sensitivity are reduced in chronically undernourished, but otherwise healthy, human subjects. *Clin. Sci.,* 2003, **104**(3), 295-302. doi: 10.1042/CS20020294.
8. Sowmya, S.; Thomas, T.; Bharathi, A.V. & Sucharita, S. A body shape index and heart rate variability in healthy Indians with low body mass index. *J. Nutr. Metab.,* 2014, 865313. doi: 10.1155/2014/865313.
9. Shetty, P.S. Nutrition transition in India. *Public Health Nutr.,* 2002, **5**(1A), 175-82. doi: 10.1079/PHN2001291.
10. Bowen, L.; Ebrahim, S.; De Stavola, B.; Ness, A.; Kinra, S.; Bharathi, A.V.; Prabhakaran, D. & Reddy, K.S. Dietary intake and rural-urban migration in India: A cross sectional study. *PLoS One*, 2011, **6**(6), e14822. doi: 10.1371/journal.pone.0014822.
11. WHO expert consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet*, 2004, **363**(9403), 157-63. doi: 10.1016/S0140-6736(03)15268-3.
12. Das, D. & Mondal, H. Evaluation of cardiac autonomic function in overweight males: A cross-sectional study. *Adv. Hum. Biol.,* 2017, **7**(1), 23-6. doi: 10.4103/2321-8568.199532.
13. Smith, P.H. & Madson, K.L. Interactions between autonomic nerves and endocrine cells of the gastroenteropancreatic system. *Diabetologia,* 1981, **20**(Suppl 1), 314-24. doi: 10.1007/BF00254498.
14. Molfino, A.; Fiorentini, A.; Tubani, L.; Martuscelli, M.; Rossi Fanelli, F. & Laviano, A. Body mass index is related to autonomic nerve system activity as measured by heart rate variability. *Eur. J. Clin. Nutr.,* 2009, **63**(10), 1263-5. doi: 10.1038/ejcn.2009.35.
15. Malik, M. Task force of the European society of cardiology and the North American society of pacing and electrophysiology. Heart rate variability: Standards of measurement, physiological interpretation and clinical use. *Eur. Heart J.,* 1996, **17**, 354-81. doi: 10.1161/01.CIR.93.5.1043.
16. Yadav, R.L.; Yadav, P.K.; Yadav, L.K.; Agrawal, K.; Sah, S.K. & Islam, M.N. Association between obesity and heart rate variability indices: an intuition toward cardiac autonomic alteration : A risk of CVD. *Diabetes Metab. Syndr. Obes.,* 2017, **10**, 57-64. doi: 10.2147/DMSO.S123935.
17. Windham, B.G.; Fumagalli, S.; Ble, A.; Sollers, J.J.; Thayer, J.F.; Najjar, S.S.; Griswold, M.E. & Ferrucci, L. The relationship between heart rate variability and adiposity differs for central and overall adiposity. *J. Obes.,* 2012, 149516. doi: 10.1155/2012/149516.
18. Quilliot, D.; Fluckiger, L.; Zannad, F.; Drouin, P. & Ziegler, O. Impaired autonomic control of heart rate and blood pressure in obesity: Role of age and of insulin resistance. *Clin. Auton. Res.,* 2001, **11**(2), 79-86. doi: 10.1007/BF02322050.
19. Freeman, R.; Weiss, S.T.; Roberts, M.; Zbikowski, S.M. & Sparrow, D. The relationship between heart rate variability and measures of body habitus. *Clin. Auton. Res.,* 1995, **5**(5), 261-6. doi: 10.1007/BF01818890.
20. Esco, M.R.; Olson, M.S.; Williford, H.N.; Blessing, D.L.; Shannon, D. & Grandjean, P. The relationship between resting heart rate variability and heart rate recovery. *Clin. Auton. Res.,* 2010, **20**(1), 33-8. doi: 10.1007/s10286-009-0033-2.
21. Kemper, K.J.; Hamilton, C. & Atkinson, M. Heart rate variability: Impact of differences in outlier identification and management strategies on common measures in three clinical populations. *Pediatr. Res.,* 2007, **62**(3), 337-42. doi: 10.1203/PDR.0b013e318123fbcc.
22. Sacha, J. & Pluta, W. Alterations of an average heart rate change heart rate variability due to mathematical reasons. *Int. J. Cardiol.,* 2008, **128**(3), 444-7. doi: 10.1016/j.ijcard.2007.06.047.
23. Spiers, J.P.; Silke, B.; McDermott, U.; Shanks, R.G. & Harron, D.W. Time and frequency domain assessment of heart rate variability: A theoretical and clinical appreciation. *Clin. Auton. Res.,* 1993, **3**(2), 145-58. doi: 10.1007/BF01819000.
24. Mukaka, M.M. Statistics corner: A guide to appropriate use of correlation coefficient in medical research. *Malawi Med. J.,* 2012, **24**(3), 69-71.
25. Masuo, K.; Mikami, H.; Ogihara, T. & Tuck, M.L. Weight gain-induced blood pressure elevation. *Hypertension*, 2000, **35**(5), 1135–40. doi: 10.1161/01.HYP.35.5.1135.
26. Arrone, L.J.; Mackintosh, R.; Rosenbaum, M.; Leibel, R.L. & Hirsch, J. Cardiac autonomic nervous system activity in obese and never-obese young men. *Obes. Res.*, 1997, **5**(4), 354-9. doi: 10.1002/j.1550-8528.1997.tb00564.x.
27. Krishna, P.; Rao, D. & Navekar, V.V. Cardiac autonomic activity in overweight and underweight young adults. *Indian J. Physiol. Pharmacol.,* 2013, **57**(2), 146-52.
28. Koenig, J.; Jarczok, M.N.; Warth, M.; Ellis, R.J.; Bach, C.; Hillecke, T.K. & Thayer, J.F. Body mass index is related to the autonomic nervous system activity as measured by heart rate variability : A replication using short term measurements. *J. Nutr. Health Aging,* 2014, **18**(3), 300-2. doi: 10.1007/s12603-014-0022-6.

CONTRIBUTORS

Mr. Jitendra Kumar Jain received his M.E. (Instrumentation & control) from Panjab University, Chandigarh. Currently pursuing his PhD from Rajasthan Technical University, Kota, Rajasthan, India. Currently working as assistant professor at Government Engineering college Bikaner, Rajasthan. He is life member of Institution of Engineers, Indian Society for Technical Education, Biomedical Engineering society of India.

In the present study, he has contributed in the study design, ECG data acquisition and result analysis.

Dr Ranjan Maheshwari received his MTech and PhD from Indian Institute of Technology, Roorkee. Currently working as professor at Rajasthan Technical University, Kota, Rajasthan, India. His area of specialisation includes Biomedical Engineering, Electrocardiogram Signal Analysis, Signal Processing, Measurement & Instrumentation. He is life member of Indian Society for Technical Education, International society of Electrocardiology and fellow member of IETE.

In the present study, he has contributed in the study design, Data interpretation and result analysis.