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RESEARCH ARTICLE

Effect of aerobic exercise as a stressor on the cardiac autonomic status of young sedentary overweight and obese females

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ABSTRACT

Background: Heart rate recovery (HRR), an important independent risk factor for cardiovascular disease and mortality is often used in research to study the cardiac autonomic status of an individual. Studies have shown that the HRR is impaired in men with metabolic syndrome, suggesting a deranged autonomic function in these individuals. An association has been found between HRR and the metabolic syndrome as well as between HRR and each of the components of this syndrome. It is well-known that HRR after exercise can be modified by weight loss, but the mechanism underlying the improvement of HRR is unclear. **Aims and Objectives:** The aim of this study is to assess and compare the exercise-induced changes in the cardiac autonomic status of young overweight and obese sedentary females and females with normal body mass index (BMI) using HRV. **Materials and Methods:** BMI and Waist/Hip ratio of 40 apparently healthy females recruited was calculated, and they were divided (following the WHO guidelines for Asians) into two groups: (1) Test group – BMI >23 Kg/m^2 and W/H>0.8 and (2) control group - BMI 18.5 to 22.9 Kg/m^2 and W/H<0.8. The level of physical activity of the study participants was assessed using the IPAQ questionnaire. Pre- and post-exercise ECG were recorded in all the females in lead II configuration. Short-term HRV analysis was performed with Kubios HRV software and tests of significance was done using repeated measures of ANOVA and Mann-Whitney *U* test using SPSS software version 23. **Results:** Not pre-exercise, but post-exercise time domain parameters were significantly differing at 1 min, 15 min, and 30 min after exercise in the test group, whereas, frequency domain parameters were showing significant differences (high LF nu, low HF nu, high LF/HF ratio) before as well as after exercise in the test group, but not significant in the control group. **Conclusion:** This shows that the sympathetic dominance after exercise is prolonged in females with higher BMI and recovery to the baseline is delayed. Hence, it is likely that these individuals could develop hypertension and other cardiac complications in their future life. Hence, the improvement of regular physical activities must be stressed on among these young females.

KEY WORDS: Heart Rate Variability; Body Mass Index; Sympathetic Dominance

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INTRODUCTION

Worldwide, the incidence of obesity seems to be increasing day by day due to sedentary lifestyle habits and unhealthy dietary patterns. Obesity is a major risk factor for various disorders such as cardiovascular diseases, diabetes mellitus, stroke, and mental illnesses.[1] Activities such as sitting and watching television for long hours and working on the computers for most hours of the day contribute as leading factors for sedentary lifestyle. Sedentary lifestyle habits along with other unmodifiable risk factors such as aging and hormonal influences[2] are considered major etiological factors for various chronic disorders.

Heart rate variability (HRV) is the beat to beat variation in the cardiac cycle. The periodic alterations in the parasympathetic and sympathetic inputs to the heart contribute to HRV. HRV analysis and interpretation are emerging as one of the early indicators of cardiac autonomic functional derangement. HRV is affected by factors such as respiration, circadian factors, environmental factors, yoga, and exercises and low HRV is a predictor risk of sudden cardiac death.[3]

Heart rate recovery (HRR), an important independent risk factor for cardiovascular disease and mortality[4] is often used in research to study the cardiac autonomic status of an individual. Studies have shown that the HRR is impaired in men with metabolic syndrome, suggesting a deranged autonomic function in these individuals. Furthermore, an association has been found between HRR and the metabolic syndrome as well as between HRR and each of the components of this syndrome.[5,6] It is well known that HRR after exercise can be modified by weight loss, but the mechanism underlying the improvement of HRR is unclear.[4] Similarly, studies on changes in HRV in response to mild aerobic exercise among young sedentary, overweight females are very limited.

Hence, in this study, the primary aim was to assess and compare the cardiac autonomic status of young overweight and obese sedentary females and females with normal body mass index (BMI) by means of HRV analysis. Similarly, the post- and pre-exercise heart rate differences of the above-mentioned groups of individuals were also compared to assess the autonomic status of these individuals in response to exercise as a stress factor.

MATERIALS AND METHODS

Forty apparently healthy females aged 18 to 25 years were recruited in the study. Institutional ethical clearance was obtained for the study. Women who performed regular physical exercises or yoga and those with a history of irregular menstrual cycles or known cases of polycystic ovarian syndrome were excluded from the study. The level of physical activity of the study participants was assessed using the IPAQ questionnaire.[7]

Height and weight of the study participants were measured using a Stadiometer and weighing scale, respectively. Using Quetelet's index (weight in Kg/[height in m]^2), BMI of the subjects was calculated. Based on BMI, the subjects were divided into two groups: (1) Women with BMI ≥23 Kg/m^2 were classified under the test group, (2) Women with BMI between 18.5 and 22.9 Kg/m^2 are classified under normal group.[8] Waist and hip circumference of the subjects were measured using an inch tape. Waist circumference was measured by placing the tape around the bare abdomen above the hip bone at the lower level of the belly button. Hip circumference was measured by placing the tape around the widest part of the hip. Waist/Hip ratio was then calculated. W/H ratio of <0.8 along with normal BMI were under control group and W/H ratio of >0.8 along with higher BMI were under test group.

Written informed consent was obtained from all the study participants before the recording. The recordings were done in between the 5th and 10th day of the menstrual cycle (proliferative phase) for all the subjects to avoid the influence of hormonal changes on HRV during various phases of menstrual cycle.[9] Subjects were instructed to avoid drinking any caffeinated beverages for 12 h before the study procedures. On the day of recording, subjects were asked to report in the lab between 9 am and 12 noon, 1-2 h after a light breakfast. They were then made to rest in supine position for 10 to 20 min following which their blood pressure was recorded using the manual sphygmomanometer. 5 min resting ECG was recorded in lead II configuration using the ECG data acquisition device. R-R intervals were derived from the ECG data and short-term HRV analysis was performed as per the recommendations of the Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology.[10] After obtaining the resting ECG data, the subjects were asked to pedal the cycle Ergometer for a maximum of 5 min or to their maximum capacity. Timings of recording were also rigid so as to avoid the circadian rhythm disturbances on the HRV.[11] Post-exercise ECG data was acquired in supine posture at 3 time points: (1) immediately after exercise, (2) 15 min after exercise, (3) 30 min after exercise. Blood pressure was also measured at the same time intervals after the exercise.

Short-term HRV analysis was performed using the Kubios HRV analysis software version 2.2. Pre- and post-exercise HRV data (time domain and frequency domain indices) was compared across the test group and control groups using student *t*-test. Pre-exercise Heart rate and Heart rate immediately and at 15 min and 30 min post-exercise were compared within and across the groups using repeated measures of ANOVA and Mann-Whitney *U*-test, respectively. Graphical plots for representation were done with Igor Pro software version 6 and statistical tests of significance were done with SPSS software version 23. $P < 0.05$ was considered statistically significant.

RESULTS

There were significant differences in BMI and Waist: Hip ratio between the test group and the control group which is the essential criteria for the study (Table 1a). Mean arterial pressure (MAP) was calculated from the blood pressure recordings taken before exercise and at specific intervals (0 min, 15 min, and 30 min) after exercise (Table 1b). Exercise-induced rise in MAP occurred in both the test group and the control group but did not return to baseline at 30 min in the test group females as it happened in the control group (*P* = 0.026).

Time Domain Analysis

Table 2a shows the pre-exercise time domain parameters of the control and test group. There was no significant difference between the two groups with respect to these parameters. However, there were significant differences between the groups immediately, 15 min and 30 min after the exercise. It was observed that even after 30 min of exercise, the parameters of the test group did not reach the pre-exercise values (Table 2b).

Table 1a: Comparison of anthropometric variables and blood pressure values between the control and test groups

Parameters	N=20 Mean (SD)		*P*
	Control (normal BMI)	Test group (higher BMI)	
Age (years)	22.31 (4.80)	21.78 (3.19)	0.514
BMI (Kg/m^2)	20.94 (1.56)	27.33 (2.14)	<0.001*
W/H ratio	0.732 (0.046)	0.814 (0.06)	0.041

*$P<0.05$ is considered significant, SD: Standard deviation, BMI: Body mass index

Table 1b: Comparison of mean arterial pressure between the test and the control groups

Time	N=20 Mean (SD)		*P* value
	Control (normal BMI)	Test group (higher BMI)	
Pre-exercise	78.82 (8.20)	80.18 (7.66)	0.618
0 min post exercise	128.64 (21.38)	132.42 (10.68)	0.211
15 min post exercise	100.68 (11.34)	118.12 (6.46)	0.130
30 min post exercise	80.88 (8.96)	98.28 (8.54)	0.026*

*$P<0.05$ is considered significant, SD: Standard deviation, BMI: Body mass index

Table 2a: Time domain analysis: Comparison of baseline time domain parameters between the test and control groups; Mean HR alone is significantly different in the test group though the absolute value falls in the normal range

Before exercise			
Parameter	N=20 Mean (SD)		*P*
	Test	Control	
Mean RR	723.6 (22.74)	759 (37.02)	0.052
Mean HR	83.27 (2.32)	78.82 (5.97)	0.020*
SDNN	45.33 (14.32)	49.2 (18.97)	0.354
RMSSD	46.38 (18.03)	48.76 (24.80)	0.428
pNN50	15.38 (5.39)	27.1 (19.86)	0.118

SD: Standard deviation, *P<0.05

Frequency Domain Analysis

The pre-exercise LF nu was significantly high, and HF nu was significantly low in overweight females when compared to females with normal BMI (Table 3a). Comparison of mean HR values before exercise and 30 min after exercise did not show any significant difference in the control group (*P* = 0.301), whereas in the test group, the mean HR was significantly high even at 30 min after exercise (*P* = 0.004) indicating the persistent dominance of sympathetic tone for a prolonged duration (Table 3b). 30 min after the exercise, LF power, HF power, LF nu, HF nu, and LF/HF ratio were significantly different in females with higher BMI.

Comparison within the groups also yielded similar results (Table 4). When the pre- and the post-exercise (30 min after exercise) results were compared, most of the parameters did not normalize even after 30 min of exercise in females with higher BMI, indicating a delay in the recovery of autonomic balance system.

DISCUSSION

HRR and changes in short-term HRV indices were assessed before, immediately and at 15 min and 30 min after aerobic exercise among normal weight and overweight and obese sedentary females. The waist to hip ratio was significantly high in the test group individuals owing to their high BMI. The baseline (pre-exercise) time domain indices indicative of cardiac parasympathetic activity (RMSSD, pNN50) and total HRV (SDNN) were not significantly different between the normal BMI and higher BMI individuals. However, among the frequency domain indices, LF nu, measure of cardiac sympathetic activity was significantly high and HF nu, a measure of cardiac parasympathetic activity was significantly low among the overweight and obese females. LF/HF measure of cardiac sympathovagal balance was significantly high in females with higher BMI. This denotes an increased resting cardiac sympathetic activity in these individuals which may be the reason for the increased resting heart rate in them. A study by Triggiani et al. has reported that the cardiac autonomic function is reduced in overweight and underweight healthy women.[12] Meanwhile, a study by Smrithi et al. has reported that the overweight adolescents have decreased vagal activity and normal sympathetic activity.[13]

Post–exercise, mean RR interval was significantly low and mean heart rate was significantly high at 15 min and 30 min in the test group. Similarly, time domain indices

Table 2b: Time domain analysis: Comparison of time domain parameters after exercise between the test and control groups; The parameters are indicative of persistent sympathetic activity in the test group even after 30 min of exercise

Time after exercise	After exercise								
	Mean (SD)								
	Mean RR			Mean HR			SDNN		
	Test	Control	*P*	Test	Control	*P* value	Test	Control	*P*
0 min	657.4 (76.16)	683.5 (87.78)	0.323	92.92 (9.95)	90.14 (10.16)	0.339	65.6 (82.67)	33.4 (5.41)	0.205
15 min	665.4 (25.75)	711.6 (48.05)	0.032*	89.89 (3.22)	85.82 (6.12)	0.053*	40.33 (22.21)	41.6 (15.38)	0.458
30 min	653.75 (10.24)	692.33 (60.47)	0.053*	92.24 (1.29)	85.9 (6.27)	0.039*	30.6 (6.10)	39.5 (3.10)	0.016*
	RMSSD			PNN50					
0 min	78.56 (13.61)	29.8 (11.89)	0.183	8.2 (10.53)	11.4 (12.35)	0.140	*$P<0.05$ is significant		
15 min	41.9 (33.73)	38.66 (18.84)	0.426	5.31 (5.50)	11.18 (10.70)	0.134			
30 min	22.84 (7.39)	34.85 (10.05)	0.038*	2.22 (2.02)	12.66 (8.72)	0.026*			

SD: Standard deviation

Table 3a: Frequency domain analysis: Comparison of baseline frequency domain parameters between the test and control groups; LF nu and HF nu values are towards predominant resting sympathetic activity in overweight and obese females

Parameter	After exercise		
	Mean (SD)		*P*
	Test	Control	
LF power	331.33 (230.27)	219.2 (98.69)	0.170
HF power	397.33 (412.7)	526.6 (504.2)	0.325
Lf nu	53.6 (15.97)	36.72 (12.37)	0.043*
HF nu	46.4 (15.97)	63.28 (12.37)	0.043*
LF/HF	1.41 (0.92)	0.62 (0.28)	0.050

SD: Standard deviation, *$P<0.05$ is significant

indicative of cardiac parasympathetic activity and total HRV were significantly low even at 30 min after exercise in the overweight and obese individuals when compared to those females in the control group. These changes reflect the reduced parasympathetic tone or an exaggerated sympathetic tone in response to exercise in these females. Measures of cardiac sympathetic activity, namely the LF Power and LF nu, and measure of sympathovagal balance, namely the LF/HF remained significantly high in the test group when compared to the control group at 30 min after the exercise. This could be due to the sustained increase in sympathetic activity following exercise in this group of individuals. In addition, HF power and HF nu of overweight individuals were significantly lower when compared to the normal weight individuals. This once again points to the decreased cardiac parasympathetic tone in overweight females. Studies have also reported that decreased cardiac vagal activity is also associated with increased risk of cardiovascular morbidity and mortality.[14]

Thus, at rest, the cardiac sympathetic activity is high, and the cardiac parasympathetic activity is low in overweight and obese females which seem to get exaggerated following simple aerobic exercise.[13] The simple aerobic exercise, a form of stressor, causes an increase in heart rate due to activation of the sympathetic nervous system or due to the withdrawal of the parasympathetic nervous system.[15] High cardiovascular reactivity to the simple aerobic exercise and a slower rate of recovery of the various cardiac autonomic parameters even after termination of exercise indicate that the cardiac autonomic control system of the overweight and obese females is not functioning to its optimal level to bring down the various parameters to baseline quickly. Hence, this may predispose these individuals at a risk of developing cardiovascular morbidities. A similar study by Christopher Cole et al. has shown that a delayed decrease in heart rate during the 1st min after graded exercise, which may be a reflection of decreased vagal activity, is a powerful predictor of overall mortality, independent of workload, the presence or absence of myocardial perfusion defects and changes in heart rate during exercise.[16]

Limitations of the Study

The number of females with higher BMI was more in the overweight category than the obese category. Also as the study was carried out only in females, the results cannot be generalized to the whole population.

CONCLUSION

Our study results have shown that the overweight and obese females have a prolonged increase in HR and HRV indices indicative of dominant cardiac sympathetic activity in response to simple aerobic exercise. Hence, it is likely that these individuals are prone to develop hypertension and other cardiac complications in their future life. Hence, practice of regular physical activities which aim at reducing the body weight must be encouraged among these young females to avoid various health hazards in future.

Table 3b: Frequency domain analysis: Comparison of frequency domain parameters after exercise between the test and control groups; The values suggest autonomic imbalance in the test group individuals

Before exercise									
Time after exercise	Mean (SD)								
	LF power			HF power			Lf nu		
	Test	Control	P	Test	Control	P	Test	Control	P
0 min	623.8 (1221.1)	83.4 (19.83)	0.175	482.2 (940.3)	136 (118)	0.218	55.02 (26.62)	46.14	0.244
15 min	223.5 (108.66)	88.2 (72.15)	0.020*	94.4 (100.7)	228.2 (139.0)	0.059	52.8 (932)	44.3 (94.2)	0.084
30 min	190.6 (23.41)	103.25 (42.11)	0.002*	76.6 (23.07)	208.5 (97.12)	0.010*	61.92 (10.42)	46.17 (11.97)	0.036*
	HF nu			LF/HF					
0 min	41.44 (12.49)	53.86 (21.78)	0.150	1.58 (0.76)	1.12 (0/84)	0.193	*P<0.05 is significant		
15 min	47.03 (9.53)	55.58 (9.37)	0.085	1.20 (0.50)	0.83 (0.30)	0.095			
30 min	38.08 (10.42)	53.82 (11.97)	0.036*	1.78 (0.70)	0.92 (0.47)	0.039*			

SD: Standard deviation

Table 4: Comparison of baseline frequency domain parameters between the test and control groups. Most of the parameters (both time domain and frequency domain) did not return to the baseline value even after 30 min of exercise in the test group as compared to the control group

Parameter	Test group			Control group		
	Pre-exercise	30 min after exercise	P	Pre-exercise	30 min after exercise	P
Mean RR	759 (37.02)	692.33 (60.47)	0.009	723.6 (22.74)	653.75 (10.24)	0.186
Mean HR	81.11 (5.97)	85.9 (6.27)	0.004	83.27 (2.32)	92.24 (1.29)	0.301
SDNN	52.66 (18.97)	39.5 (3.10)	0.106	40.4 (8.59)	30.6 (6.10)	0.425
RMSSD	48.76 (24.80)	34.85 (10.05)	0.023	46.38 (18.03)	22.84 (7.39)	0.350
pNN50	27.1 (19.86)	12.66 (8.72)	0.010	15.38 (5.39)	2.22 (2.02)	0.276
LF power	219.2 (98.69)	103.25 (42.11)	0.188	331.33 (230.27)	190.6 (23.41)	0.199
HF power	526.6 (504.2)	208.5 (97.12)	0.118	397.33 (412.7)	76.6 (23.07)	0.372
Lf nu	36.72 (12.37)	46.17 (11.97)	0.046	53.6 (15.97)	61.92 (10.42)	0.281
HF nu	63.28 (12.37)	53.82 (11.97)	0.021	46.4 (15.97)	38.08 (10.42)	0.424
LF/HF	0.62 (0.28)	0.92 (0.47)	0.039	1.41 (0.92)	1.78 (0.70)	0.264

SD: Standard deviation

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