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Autonomic response of gradient exercise testing protocol in normotensive, overweight, and pre-hypertensive individuals: a prospective, observational, and analytical study

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Abstract: Background: Coronary artery disease (CAD) is increasing day by day in young Indian population with increase in risk factors such as obesity, hypertension etc. Although in early age, these risk factors are clinically asymptomatic but physiologically they are symptomatic. These symptoms can be best assessed by assessing the response of autonomic nervous system Therefore the *purpose* of this study was to compare the autonomic response of gradient exercise testing protocol in normotensive, overweight, and pre-hypertensive subjects in the form of chronotropic response to exercise, inotropic reponse, heart rate recovery, blood pressure recovery, BRPE, and heart rate variability so that the physiological abnormalities can be corrected.

Results: There were significant differences ($p < 0.05$) found in gradient exercise testing protocol in diastolic blood pressure in normotensive, in heart rate variability in overweight and in both systolic as well as diastolic blood pressure in pre-hypertensive subjects.

Conclusion: Gradient exercise testing protocol can be best utilized as a clinical tool in normotensive, overweight, and pre-hypertensive subjects for the assessment of autonomic nervous system which provides diagnostic and prognostic information regarding cardiovascular disease or abnormalities.

Keywords: Autonomic nervous system, Chronotropic response, Inotropic response, Borg's rating of perceived exertion (BRPE), Heart rate recovery (HRR), Blood pressure recovery, Heart rate variability (HRV)

Background

Coronary artery disease, also known as CAD in short, is the disease of coronary blood vessels of the heart and is mainly caused due to atherosclerosis formation resulting in chest pain (stable angina), heaviness in the chest, shortness of breath, excessive sweating, heart attack and other symptoms [1].

The other common risk factors for causing coronary artery disease, apart from atherosclerosis, involves high blood pressure, overweight or obesity, high cholesterol, smoking and tobacco use, diabetes, sedentary lifestyles, and psychosocial stress. All these factors are the important determinants of coronary artery disease and are increasing day by day in young Indian population, especially the people with overweight and pre-hypertension presents a relatively high risk of developing coronary artery disease comparatively to normotensives [2, 3]. They may have severe impact on heart rate and blood pressure which is mediated primarily by the direct activity of autonomic nervous system [4, 5].

The exercise testing has been considered a potential useful technique for screening coronary artery disease

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[6]. It can elicit the cardiovascular abnormalities, which are usually absent at rest, by evaluating several discrete aspects of exercise testing including chronotropic response, inotropic response, Borg's rating of perceived exertion (BRPE), heart rate recovery (HRR), blood pressure recovery (BPR), and heart rate variability (HRV). All these parameters are the best method of assessing an individual's physical capacity and effort tolerance for exercise and also the effectiveness of autonomic nervous system on cardiovascular response to exercise [7, 8].

Treadmill exercise stress testing results in higher maximal oxygen uptake and has greater sensitivity for detecting coronary artery disease [9]. The protocols typically start at very low intensity and/or at level gradient and progressively rise to higher speeds and/or gradients each 2–3 min until fatigue or the development of symptoms or signs of cardiac disease. Blood pressure (BP) is a mandatory safety measure during graded intensity clinical exercise stress testing. While it is generally accepted that exercise hypotension is a poor prognostic sign linked to severe cardiac dysfunction, recent meta-analysis data also implicate excessive rises in submaximal exercise BP with adverse cardiovascular events and mortality, irrespective of resting BP.

In recent years, data has emerged suggesting that BP responses to exercise testing could provide useful clinical information independent from resting BP. Although more data is needed to derive submaximal normative BP thresholds, the association of a hypertensive response to exercise with increased cardiovascular risk may be due to underlying hypertension that has gone unnoticed by conventional resting BP screening methods [10]. Delayed BP decline during recovery is also associated with adverse clinical outcomes. Thus, above and beyond being used as a routine safety measure during stress testing, exercise (and recovery) BP may be useful for identifying high-risk individuals and also as an aid to optimize care through appropriate follow-up after exercise stress testing.

Similarly, heart rate decreases exponentially at the end of exercise followed by a slower return to the pre-exercise level [11–14]. Any impairment in autonomic regulation of cardiovascular function results in abnormal HR recovery or a less pronounced decrease of HR immediately after exercise cessation. This itself is an independent predictor of all-cause mortality among subjects underlying exercise and is associated with a higher risk of cardiovascular events and/or sudden death [15–22].

Heart rate variability (HRV) is also one of the widely used noninvasive tools for diagnosing and monitoring the dynamic autonomic response during exercise by analysis of ECG which determines the variations in consecutive time interval between peaks of QRS complex called RR interval [23, 24]. HRV is thought to represent the autonomic balance between sympathetic and parasympathetic pathways through low frequency (LF), high frequency (HF), and LF/HF ratio. Any abnormalities in LF, HF, and LF/HF values have been used as a measure for predicting future coronary events [25–27]. Therefore, ANS plays an essential role in the regulation of cardiovascular system that serve to maintain homeostasis.

Many previous studies have been performed on gradient exercise testing protocol in normotensive subjects for the assessment of Autonomic nervous system but there are very few studies who investigated the autonomic nervous system response in exercise testing in pre-hypertensive and overweight individuals [6, 17, 19]. Hence, to evaluate the response of the autonomic nervous system especially in pre-hypertensive and overweight individuals become necessate. In this context, the main purpose of this study is to observe and compare the autonomic response of Gradient exercise testing protocol in normotensive, overweight, and pre-hypertensive subjects. By investigating the autonomic response in normotensive, overweight and pre-hypertensive subjects, the study will help in development of the safe exercise program that not only promote the fitness in young adults but also help in preventing CAD morbidity and mortality in future by making them aware of risk factors regarding coronary artery disease.

Methods

Strobe guidelines

This investigation is based on STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) guideline, which provides comprehensive information concerning the study design, setting, variables, participants, measurements, data sources, quantitative variables description, description of potential sources of bias, statistical methods, results, limitation, and funding.

Aim of the study

This research study was aimed to observe and compare the autonomic response of gradient exercise testing protocol in normotensive, overweight, and pre-hypertensive subjects in the form of chronotropic response to exercise, inotropic reponse, heart rate recovery, blood pressure recovery, BRPE, and heart rate variability.

Study design

Prospective, observational, and analytical study.

Study setting and the characteristics of participants or description of materials

This study was conducted in Autonomic function lab of Deemed University, Dehradun, India. Total 100 subjects were registered and screened via convenient sampling from the population of University. Each subject was assessed and examined on the basis of assessment performance. Out of which 30 subjects were recruited who were found suitable for the study according to the inclusion and exclusion criteria. The subjects were then allocated into 3 groups—normotensive, overweight, and prehypertensive (as shown in Fig. 1) by a staff who was not a part of research team. *Sample size* was determined by previous similar studies and through consensus of the authors and research committee.

The inclusion criteria were (1) 18–30 years of age, (2) both male and female, (3) normotensive subjects with systolic B.P. < 120 mmHg, diastolic B.P. < 80 mmHg, and BMI = 19–24.9 kg/mtr^2, (4) pre-hypertensive subjects with systolic B.P. = 120–139 mmHg and diastolic B.P. = 80–89 mmHg, (5) overweight subjects with BMI = 25–29.9 kg/mtr^2, (6) participants, who were apparently healthy, free from cardiac risk factors, cardiopulmonary, metabolic, and/or orthopedic disorders, and currently not taking any medical prescription, (7) subjects who were cooperative, performing test at THR 80% max HR for running exercises.

The exclusion criteria were (1) subjects who were uncooperative and did not match the inclusion criteria, (2) subjects having orthopedic and musculoskeletal conditions, (3) subjects who did not pass the screening.

Variables/outcome measures were (1) body mass index (BMI) (weight in kg/height in m^2), (2) chronotropic

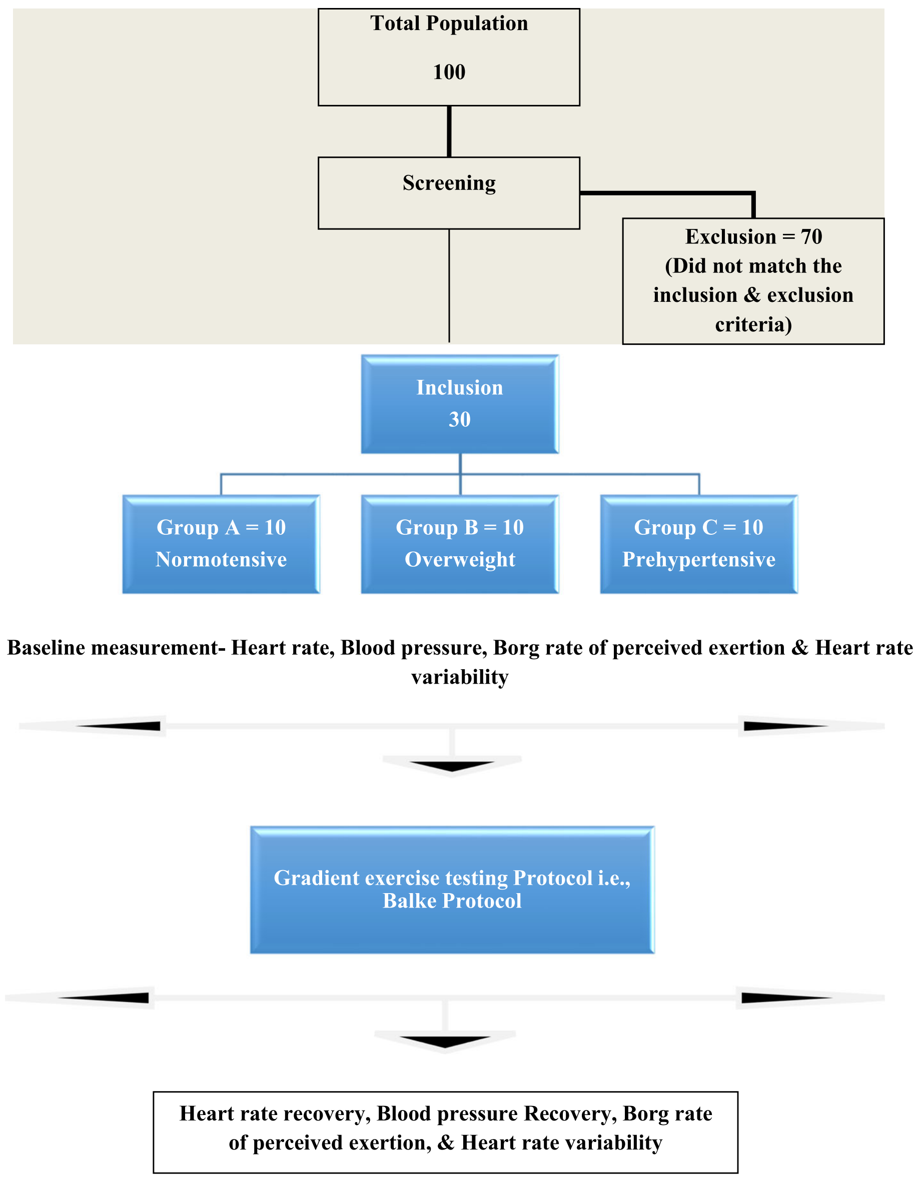

Fig. 1 Flowchart 1—procedure

response, (3) inotropic response (BP), (4) target heart rate using Karvonen formula, (5) heart rate recovery, (6) blood pressure recovery, (7) heart rate variability.

Procedure

Prior to start the procedure, proper explanation of the procedure was taught to the subjects including its risks and possible complications. A proper demonstration was provided of how to use the treadmill. Subjects were also explained about the safety measures during exercise testing like if they feel unexpected pain or discomfort, they may pull safety button to stop treadmill.

All the subjects were then made to perform gradient exercise testing protocol, intensity of which was based on Karvonen's formula. Testing sessions were performed at the same time of the day in a quiet and well ventilated environment. The anthropometric parameters were measured in the beginning of the procedure including height in centimeter, weight in kilogram, and body mass index. Data collection was done by assessor who was blinded to the groups.

Pulse rate and blood pressure were measured after ensuring that the subjects have relaxed at least for 5 min. Pulse rate was measured by examining radial pulse at rest, both before and immediately after cessation of exercise and then after every minutes up to 3 min of recovery. Pulse rate during exercise was noted down from the treadmill monitor. Whereas, blood pressure was measured by aneroid sphygmomanometer minimum three times taking the first and the fifth phases of Korotkoff sounds as systolic and diastolic values, respectively. The average of the 3 readings was used to determine resting BP.

Heart rate variability was performed with subjects seated on a chair with their back and arms fully supported. German silver plated surface electrodes were used for ECG recording. Electrolyte jelly was employed as an interface between the electrodes and the source during event. Recording was performed for 5 min using frequency domain (FFT).

BRPE was also obtained immediately before the exercise testing using an oral questionnaire from the subjects.

Potential source of bias

In an effort to control potential sources of bias, all the subjects were instructed to wear loose fitting comfortable clothes and sports shoes. They were instructed to avoid heavy meal, smoking, alcohol, and caffeine at least 3 h prior to testing and to refrain from strenuous exercise 12 h before testing. They were also advised to drink plenty of fluids in the 24 h preceding the assessment and sleep for at least 6–8 h the night before the test.

Protocol

Gradient exercise testing protocol, i.e., Balke protocol, first developed by Hanson in 1984, was used in the study. It is a 25–30-min protocol which is slightly different for men and women. It uses a constant speed of 3.3 mph, i.e., 5.3 km/h for males and 3.0 mph, i.e., 4.8 km/h for females. The test began by setting the incline at 0%. The inclination was increased by 2% (1.2°) after 1 min and 1% (0.6°) thereafter every minute for males and 2.5% (1.4°) every 3 min for females. The pace was maintained throughout the testing and the inclination was increased until the subject reached his/her target heart rate or exhausted and cannot continue anymore.

Subjects were exercised until reaching an age-specific target heart rate or the development of symptoms necessitating termination of the test.

Post-exercise BRPE, HRR, BPR, and HRV measurement

As soon as the exercise testing was finished, BRPE was obtained from the subjects through an oral questionnaire. Heart rate recovery (HRR) was measured by HR_{peak}–HR after 1 min rest, where peak or maximal HR was obtained with the subjects standing on the treadmill at peak exercise and post-exercise HR was measured for 3 min after completion of the exercise testing protocol.

Blood pressure recovery was measured by using an aneroid sphygmomanometer, taking the first and the fifth phases of Korotkoff sounds as systolic and diastolic values, respectively. The average of the 3 readings was used to determine resting BP in every 5 min and discontinued as soon as both SBP and DBP returned to the pre-exercise value.

HRV was also performed in the end after ensuring that the subjects have relaxed at least for 30 min using frequency domain (FFT).

Data analysis

Statistical analysis was done by using SPSS version 22, where data were reported as mean ± std. dev. and statistical significance was assumed at $p \leq 0.05$. Both intragroup and inter-group analyses were performed.

Intragroup analysis were performed between pre- and post-readings of SBP, DBP, and HRV in normotensive, overweight, and pre-hypertensive subjects individually by using parametric students' paired *t* test for gradient exercise testing protocol.

Intergroup analysis was performed among normotensive, overweight, and pre-hypertensive subjects in pre- and post-difference of HR, SBP, DBP, BRPE, and HRV for gradient exercise testing protocol by using parametric test—one way analysis of variance (ANOVA).

The figures were made in Microsoft office Excel 2007 and Microsoft Office Word 2007 in Microsoft Office Window 2007.

Results

In the present study, a total of 30 subjects (including males and females) were selected based on inclusion and exclusion criteria. They were then divided into three groups as normotensive, overweight, and pre-hypertensive with 10 subjects in each group. The *mean age* of normotensive, overweight, and pre-hypertensive were 20.9 years, 21.7 years and 21.7 years respectively which showed homogeneity of the groups. The *mean BMI* of normotensive, overweight, and pre-hypertensive were 22.33 kg/mt^2, 27.1 kg/mt^2, and 23.66 kg/mt^2, respectively.

Intragroup analysis

On comparing SBP in normotensive group in gradient exercise testing protocol having mean ± SD 112.80 ± 5.59 (pre) and 113.60 ± 11.30 (post), with t value 0.24 and p value 0.81, which is ≥ 0.05. This shows statistically non-significant difference.

On comparing DBP in normotensive group in gradient exercise testing protocol having mean ± SD 71.60 ± 6.72 (pre) and 65.60 ± 7.23 (post), with t value 2.84 and p value 0.01, which is ≤ 0.05. This shows statistically significant difference.

On comparing SBP in overweight group in gradient exercise testing protocol having mean ± SD 110.60 ± 5.50 (pre) and 112.80 ± 10.96 (post), with t value 0.68 and p value 0.51, which is ≥ 0.05. This shows statistically non-significant difference.

On comparing DBP in overweight group in gradient exercise testing protocol having mean ± SD 69.80 ± 5.20 (pre) and 69.60 ± 12.53 (post), with t value 0.06 and p value 0.94, which is ≥ 0.05. This shows statistically non-significant difference.

On comparing SBP in pre-hypertensive group in gradient exercise testing protocol having mean ± SD 127.20 ± 4.44 (pre) and 120.20 ± 9.58 (post), with t value 2.51 and p value 0.03, which is ≤ 0.05. This shows statistically significant difference.

On comparing DBP in pre-hypertensive group in gradient exercise testing protocol having mean ± SD 82.80 ± 3.91 (pre) and 72.00 ± 15.11 (post), with t value 2.88 and p value 0.01, which is ≤ 0.05. This shows statistically significant difference.

On comparing LF in overweight group in gradient exercise testing protocol having mean ± SD 75.70 ± 9.00 (pre) and 61.76 ± 14.21 (post), with t value 2.98 and p value 0.01, which is ≤ 0.05. This shows statistically significant difference.

On comparing HF in overweight group in gradient exercise testing protocol having mean ± SD. 24.21 ± 9.00 (pre) and 38.24 ± 14.21 (post), with t value 2.98 and p value 0.01, which is ≤ 0.05. This shows statistically significant difference.

On comparing LF/HF in overweight group in gradient exercise testing protocol having mean ± SD 3.72 ± 1.90 (pre) and 2.04 ± 1.37 (post), with t value 2.74 and p value 0.02, which is ≤ 0.05. This shows statistically significant difference.

The above data has shown that on comparing pre- and post-readings of SBP, DBP, and HRV in gradient exercise testing protocol in normotensive, overweight, and pre-hypertensive subjects individually, there were significant differences ($p < 0.05$) found in diastolic blood pressure in normotensive, in heart rate variability (LF, HF, LF/HF) in overweight and in both systolic as well as diastolic blood pressure in pre-hypertensive subjects. Baseline characteristics and descriptive statistics of above outcome measures of the subjects are shown in Tables 1 and 2.

Intergroup analysis

On comparing pre- and post-difference of HR, SBP, DBP, BRPE, and HRV for gradient exercise testing protocol among normotensive, overweight, and pre-hypertensive subjects, no significant difference ($p \geq 0.05$) was found in any of the outcome variables (Table 3).

Discussion

The present study observed and compared the autonomic response of gradient exercise testing protocol in normotensive, overweight, and pre-hypertensive subjects in the form of chronotropic response, inotropic response, Borg rating of perceived exertion, heart rate recovery, blood pressure recovery, and heart rate variability. The mean age of normotensive, overweight, and pre-hypertensive were 20.9 years, 21.7 years, and 21.7 years respectively with standard deviation of 1.37, 2.35, and 1.82 respectively. The mean BMI of normotensive, overweight, and pre-hypertensive were 22.33 kg/mt^2, 27.1 kg/mt^2, and 23.66 kg/mt^2 respectively with standard deviation of 1.81, 1.47, and 1.47 respectively.

Heart rate recovery in gradient exercise testing protocol in normotensive, overweight, and pre-hypertensive subjects

On comparing heart rate recovery (HRR) in gradient exercise testing protocol among normotensive, overweight, and pre-hypertensive group having mean ± SD 32.6 ± 19.44, 23.70 ± 6.20, and 31.80 ± 12.10 respectively with

Table 1 Comparison of mean age and BMI among normotensive, overweight, and pre-hypertensive groups

Group	Age (mean ± SD)	BMI (kg/mtr^2)
Normotensive	20.9 ± 1.37	22.33 ± 1.81
Overweight	21.7 ± 2.35	27.1 ± 1.47
Prehypertensive	21.7 ± 1.82	23.66 ± 1.47

Table 2 Intragroup analysis in gradient exercise testing protocol using paired *t* test

Group	Variables (gradient)	Pre (mean ± std dev.)	Post (mean ± std dev.)	*t* value	*P* value
Normotensive	SBP	112.80 ± 5.59	113.60 ± 11.30	0.24	0.81
	DBP	71.60 ± 6.72	65.60 ± 7.23	2.84	0.01*
	LF	49.24 ± 18.68	42.13 ± 17.22	1	0.34
	HF	50.76 ± 18.68	57.87 ± 17.22	1	0.34
	LF/HF	1.29 ± 1.02	0.89 ± 0.64	1.26	0.23
Overweight	SBP	110.60 ± 5.50	112.80 ± 10.96	0.68	0.51
	DBP	69.80 ± 5.20	69.60 ± 12.53	0.06	0.94
	LF	75.70 ± 9.00	61.76 ± 14.21	2.98	0.01*
	HF	24.21 ± 9.00	38.24 ± 14.21	2.98	0.01*
	LF/HF	3.72 ± 1.90	2.04 ± 1.37	2.74	0.02*
Pre-hypertensive	SBP	127.20 ± 4.44	120.20 ± 9.58	2.51	0.03*
	DBP	82.80 ± 3.91	72.00 ± 15.11	2.88	0.01*
	LF	66.77 ± 14.55	58.00 ± 17.85	1.84	0.09
	HF	33.13 ± 14.30	42.00 ± 17.85	1.87	0.09
	LF/HF	2.47 ± 1.28	1.93 ± 1.60	0.92	0.38

Abbreviations: *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *LF* low frequency (denotes heart rate variability), *HF* high frequency (denotes heart rate variability), *LF/HF* ratio of low frequency and high frequency
*Significant—$p < 0.05$

p value 0.29, which is ≥ 0.05, statistically no significant difference was found but the results showed that post-exercise heart rate decreased with decrease in sympathetic (LF), sympathetic/parasympathetic (LF/HF) and increase in parasympathetic (HF) activity. Increased vagal activity has been suggested to be responsible for the fast decrease of HR during the first minute after exercise cessation [28, 29]. However, an increase in vagal activation as well as a decrease in sympathetic activation has been detected during the first minutes of the recovery by Savin et al. [30]. So, it confers that the immediate first minute decline in HR after exercise cessation is mainly vagal in origin [28–31].

Because of the strong relationship between vagal tone and cardiac risk, investigators studying clinical populations suspected and confirmed that attenuated HR recovery, as a reflection of impaired vagal tone, would be predictive of an increased risk of death [17, 32–34].

In the present study, using the original 12 bpm or less at 1 min of recovery as the cutoff for abnormal (Nishime et al.), it was observed that recovery dynamics of HR in 1 min was more than 12 bpm. A possible explanation for this result is that HRR was calculated as [HRR = HR_{peak} − HR after 1 min rest].

A decrease in heart rate from peak exercise to 1 minute of recovery of 12 bpm or less after graded exercise testing was found to be a powerful predictor of overall mortality in the study of Cole et al. [32]. In addition, Nissinen et al. [35] found that the slow recovery of heart

Table 3 Intergroup analysis in gradient exercise testing protocol using ANOVA

Variable (gradient)	Normotensive (mean ± SD)	Overweight (mean ± SD)	Pre-hypertensive (mean ± SD)	*F* value	*P* value
HRR (bpm)	32.6 ± 19.44	23.70 ± 6.20	31.80 ± 12.10	1.29	0.29
SBPR (mm Hg)	0.80 ± 10.25	2.20 ± 10.17	7.00 ± 8.80	2.57	0.09
DBPR (mm Hg)	6.00 ± 6.66	0.20 ± 9.49	10.80 ± 11.85	3.07	0.06
LF (n.u.)	7.11 ± 22.37	14.03 ± 14.84	8.77 ± 15.02	0.41	0.66
HF (n.u.)	7.11 ± 22.37	14.03 ± 14.84	8.87 ± 14.94	0.41	0.66
LF/HF (%)	0.39 ± 0.98	1.67 ± 1.92	0.53 ± 1.83	1.83	0.17
Change in BRPE	3.50 ± 1.50	3.10 ± 1.37	2.60 ± 1.26	1.06	0.36

Abbreviations: *HRR* (bpm) heart rate recovery (beats per minute), *SBPR* systolic blood pressure recovery, *DBPR* diastolic blood pressure recovery, *LF* low frequency (denotes heart rate variability), *HF* high frequency (denotes heart rate variability), *LF/HF* ratio of low frequency and high frequency, *BRPE* Borg's Rate of Perceived Exertion rate during the first recovery minute after exhaustive exercise was related to increased amount of deaths among patients with former myocardial infarct.

It was also observed that subjects with high peak heart rate had greater decline in HR in first minute of recovery. So it can say that higher the peak heart rate, grater is the decline in heart rate in first minute of recovery. It is believed that recovery from dynamic exercise is associated with the cessation of the primary exercise stimulus from the brain (i.e., central command from the cerebral motor cortex), which seems to be responsible for the early recovery phase of HR [36].

Borg's rate of perceived exertion in gradient exercise testing protocol in normotensive, overweight, and pre-hypertensive subjects

On the basis of comparison of change in BRPE in gradient exercise testing protocol among normotensive, overweight, and pre-hypertensive group having mean ± SD 3.50 ± 1.50, 3.10 ± 1.37, and 2.60 ± 1.26 respectively with p value 0.36, which is ≥ 0.05, statistically no significant difference was found. Although the protocol used was submaximal exercise testing protocol, but the exertion level during the protocol was observed significantly low when measured through BRPE scale ranges between 1 and 10 on category ratio scale.

Blood pressure recovery and heart rate variability in gradient exercise testing protocol in normotensive, overweight, and pre-hypertensive subjects

On the basis of comparison of SBP recovery in gradient exercise testing protocol among normotensive, overweight, and pre-hypertensive group having mean ± SD 0.80 ± 10.25, 2.20 ± 10.17, and 7.00 ± 8.80 respectively with p value 0.09, which is ≥ 0.05, statistically no significant difference was found.

Similarly, on the basis of comparison of DBP recovery in gradient exercise testing protocol among normotensive, overweight, and pre-hypertensive group having mean ± SD 6.00 ± 6.66, 0.20 ± 9.49, and 10.80 ± 11.85 respectively with p value 0.06, which is ≥ 0.05, statistically no significant difference was found.

While comparing pre- and post-findings of systolic and diastolic blood pressure response in gradient exercise testing protocol in normotensive, overweight, and pre-hypertensive subjects individually; significant differences were found in diastolic blood pressure in normotensive subjects having mean ± SD 71.60 ± 6.72 (pre) and 65.60 ± 7.23 (post), with p value 0.01, which is ≤ 0.05; in systolic blood pressure in pre-hypertensive subjects having mean ± SD 127.20 ± 4.44 (pre) and 120.20 ± 9.58 (post), with p value 0.03, which is ≤ 0.05 and also in diastolic blood pressure in pre-hypertensive subjects having mean ± SD 82.80 ± 3.91 (pre) and 72.00 ± 15.11 (post) with p value 0.01, which is ≤ 0.05 (Fig. 2). This was probably due to change in heart rate variability and can be denoted as low frequency (LF) or high frequency (HF).

A possible explanation is that in the present study it was observed that following gradient exercise testing protocol, BP decreased with decrease in sympathetic (LF), sympathetic/parasympathetic (LF/HF), and increase in parasympathetic (HF) activity (Fig. 3). It has been stated by several studies that during exercise, HRV is significantly decreased, as sympathetic nervous activity is augmented and vagal activity attenuated. But as soon as the exercise stops, changes occur in baroreceptor function, central command, and cardiac pre-load and contractility, which affect cardiac functions together with increased vagal activity resulting in decline in BP [37–40].

Therefore, based on the results of the present study, it can conclude that there is a positive correlation between blood pressure recovery and heart rate variability. Although, the present study has not shown statistically significant correlation between BP recovery and HR variability in overweight group.

The other possible reason could be vasodilatation of the muscle vasculature. Palatini [41] has suggested that following exercise, blood pressure rapidly returned to normal. This may be due to transient pressure "undershoot" caused by a pooling of blood in the dilated, previously exercised muscle beds.

Limitation of the study

The subjects were selected by convenient sampling. Sample population was limited to young subjects only, i.e., 18–30 years of age. Also, the study was carried out with spontaneous breathing during rest, an exercise session, and a controlled recovery session. It is known that both tidal volume and breathing frequency may affect high frequency component of HRV at rest. Increased tidal volume has been found to increase HRV, whereas increased breathing frequency decreases it [42–44].

Conclusion

The study concluded that gradient exercise testing protocol is proved to be more effective in normotensive and pre-hypertensive subjects among all the three groups (normotensive, overweight, and pre-hypertensive) for the assessment of autonomic nervous system. This will help to develop a safe exercise program that not only promote the fitness in young adults but also help in preventing CAD morbidity and mortality in future by making them aware of risk factors regarding coronary artery disease.

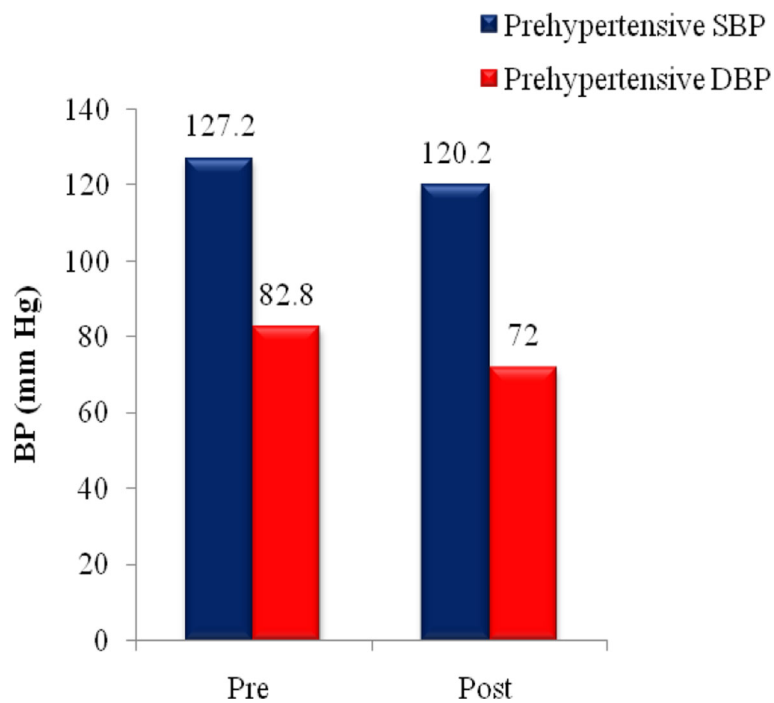

Fig. 2 Pre- and post-comparison of SBP and DBP in pre-hypertensive group in gradient exercise testing. *Abbreviations*: SBP systolic blood pressure; DBP diastolic blood pressure; BP blood pressure

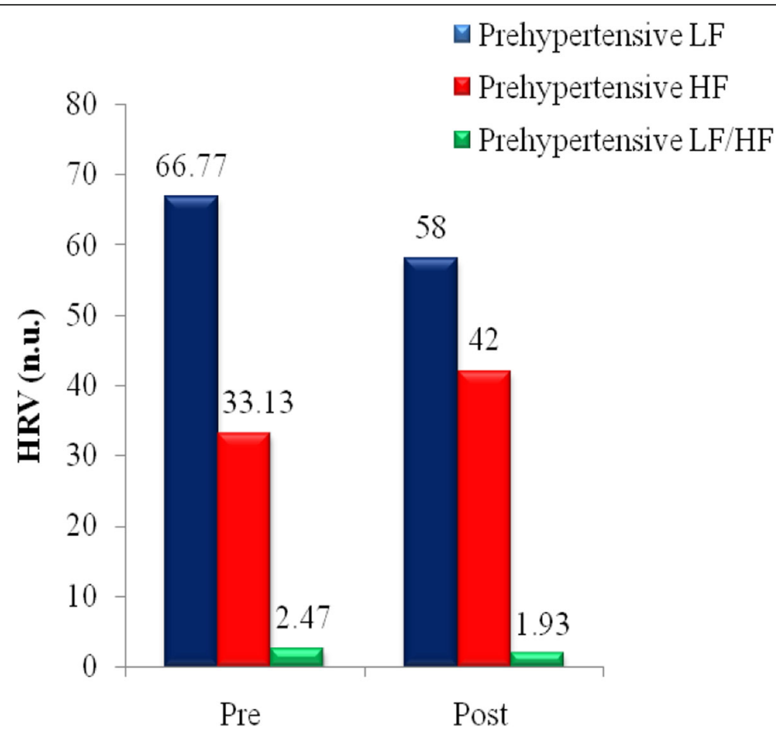

Fig. 3 Pre- and post-comparison of heart rate variability in pre-hypertensive group in gradient exercise testing. *Abbreviations*: HRV heart rate variability; LF low frequency (denotes heart rate variability); HF high frequency (denotes heart rate variability); LF/HF ratio of low frequency and high frequency

Operational definition

- Pre-autonomic response measurement at rest or before introduction of gradient exercise testing protocol.
- Post-autonomic response measurement after introduction of gradient exercise testing protocol.

Abbreviations
SBP: Systolic blood pressure; DBP: Diastolic blood pressure; LF: Low frequency (denotes heart rate variability); HF: High frequency (denotes heart rate variability); LF/HF: Ratio of low frequency and high frequency; HRR (bpm): Heart rate recovery (beats per minute); SBPR: Systolic blood pressure recovery; DBPR: Diastolic blood pressure recovery; BRPE: Borg's Rate of Perceived Exertion

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Authors' contributions
Conception and design of work: NB, AN, YS. Acquisition: NB, AN, YS. Analysis and/or interpretation of data: NB, AN, YS, SA. Drafting the manuscript: NB, AN, YS, SA. Revising the manuscript: NB, AN, YS, SA. Approval of submitted version of the manuscript: NB, AN, YS, SA. All authors have read and approved the manuscript.

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Declarations

Ethics approval and consent to participate
The study was ethically approved by paramedical committee of Swami Rama Himalayan University, Dehradun, India (reference number is not available). All the participants have given written consent. Data is also available.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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