Research Article

Variation and association of body mass index with myocardial oxygen consumption; a gender-based study in young population

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Abstract

Background: Regular exercise improves health and prevents many diseases. Exercise testing can be used as a diagnostic tool to unmask subclinical conditions such as coronary artery diseases and also monitor the effectiveness of therapeutic measures. Rate pressure product is a measure of stress put on cardiac muscle based on heart rate and systolic blood pressure. Numerous studies attempting to explain gender differences in cardiovascular response to isometric exercise are inconsistent at best and conflicting. **Aims and Objective:** The purpose of this study was to determine if the cardiovascular responses to dynamic exercises differ between healthy normotensive men and women students depending on their BMI ratio. **Materials and Methods:** This study consisted of young individuals (127 men and 123 women) of age group 18–20 years studying in first-year MBBS. Depending on their anthropometric measurements, classification was done as, normal, overweight, and obese groups based on WHO recommendations. Blood pressure and heart rate were recorded before, immediately after cessation of exercise, after 3 min, and after 5 min of recovery. MVo_2 was measured by the rate pressure product (RPP) calculated as product of heart rate and systolic blood pressure. **Result:** Postexercise HR, SBP, DBP, and RPP were significantly greater in men than women. Highly significant increase in postexercise HR, SBP, DBP and RPP was observed in men compared to women. **Conclusion:** Men undergo significant changes in cardiac output, total peripheral resistance, or increase in level of circulating catecholamines mainly epinephrine with many possible explanations.

KEY WORDS: Heart Rate; Obesity; Rate Pressure Product

Introduction

Obesity is a common condition that develops from the interaction between the genotype and the environment and involves social, behavioral, cultural, physiological, metabolic, and genetic factors.[1–3] Obesity has an important negative impact on health in a population and is characterized by hemodynamic and metabolic alterations. Overweight and obesity are major risk factors for cardiovascular diseases. Exercise is a form of self-induced stress leading to circulatory and respiratory adjustments in the body to the resultant increased metabolic demand. These changes depend on the specific types of exercises undertaken, isometric or isotonic. Past studies investigating isometric hand grip exercises featured the use of various body positions.[4] Upper limb joint placements across gender and among different age groups with a view to providing normative data or rehabilitation.[5–10] Isometric or static exercises are characterized by change in the muscle tension with no change in the muscle length whereas

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isotonic or dynamic exercises exhibit change in the muscle length with tension remaining the same. RPP, also known as cardiovascular product or double product, is the product of heart rate and systolic blood pressure, which is used in cardiology and exercise physiology to indirectly determine the MVo_2 and thus cardiovascular risk of subjects. RPP is a correlate of myocardial oxygen consumption, and hence of work load of the heart.[1,2,11,12] It is considered a determinant of cardiovascular risk, since its increase precedes ischemic events.[13,14] RPP is used to measure the workload or oxygen demand of the heart and reflects hemodynamic stress. RPP is said to be raised in obesity due to cardiac remodelling or sympathovagal imbalance.[13,15,16] Thus RPP is used to measure the workload or oxygen demand of the heart, and reflects hemodynamic stress. Exercise stress testing is an accepted mode of evaluating the peak oxygen consumption and cardiopulmonary status. RPP increases with the increased workload on the heart to provide the adequate blood supply to the myocardium during exercise.[11,12] There are not many studies on RPP changes to submaximal exercise in overweight and obese young adults. Hence, this study was under taken with the aim of evaluating the effect of overweight and obesity on RPP and the effect of submaximal steady exercise on the RPP in apparently healthy overweight and obese young adults. There are reports suggesting gender difference in the cardiovascular response to exercise; and this study further analyzes the differences seen in this response among the young male and female subjects.

Materials and Methods

This study was conducted on 250 normotensive medical students of first-year MBBS (127 women and 123 men) of age group 18–20 years. This study was conducted and the data were collected during routine practical classes when the students were actually performing anthropometry and studying the effect of exercise on blood pressure to avoid ethical issues. Students were grouped into normal weight, overweight, and obese; distribution was different for boys and girls. Subjects with previous history of cardiovascular, neurological disorders, trained athletes, or any disability limiting the ability to perform upper limb exercise were excluded from the study. The subjects were informed about the procedure and consent was obtained for the procedure. The height was recorded without wearing shoes and with light clothes on a wall-mounted measuring tape to the nearest of centimeters. Weight was recorded with standard weighing scale without shoes and light clothes with a least count of 0.1 kg. The BMI was obtained by dividing the weight by the square of the height, that is, BMI = weight in kg/height in m^2. Normal weight students with BMI < 22.9 kg/m^2 (54 male, 51 female subjects); overweight with BMI $\geqslant 23$ to 24.9 kg/m^2 (37 male, 40 female subjects); obese with BMI $\geqslant 25$ kg/m^2 (32 male, 36 female subjects). Subjects were briefed about the experiment protocol and were familiarized with the set up. After 10 min of relaxation, resting blood pressure (BP) was measured in the sitting position using a mercury sphygmomanometer by auscultatory method and pulse rate was measured by examining radial pulse, disconnect the manometer of BP apparatus from its rubber cuff. With rubber cuff on arm, the subject was asked to do spot jogging at a rate of 30 per min, rate being determined by meteronome, the exercise was stopped when the subjects were not able to continue, the subjects were relaxed and the blood pressure was again recorded at the end of exercise and after 5 min, respectively. Direct measurement of MVo_2 is difficult in routine clinical practice but it can be easily calculated by indirect methods such as stroke work, Fick's Principle, the tension time index, and rate pressure product (RPP). RPP is the product of heart rate and systolic blood pressure [RPP = Systolic blood pressure (SBP) $\times$ heart rate (HR)]. RPP was calculated at rest and after exercise.

Statistical Analysis

Student's paired *t*-test was used to compare intragroup pre- and postexercise cardiovascular parameters. Unpaired *t*-test was used to compare physical characteristics and pre- and postexercise cardiovascular parameters between genders. Level of significance was set at $p < 0.05$. Pearson's correlation coefficients were estimated to quantify the linear relationship between the indices of obesity and RPP.

Results

Of the 250 students (127 women and 123 men), data were analyzed separately for both men and women with respect to BMI and blood pressure indices (Tables 1 and 2). Postexercise cardiovascular parameters were significantly greater ($p < 0.05$) than baseline values without gender bias. However, the weight and BMI of the female participants was significantly ($p < 0.05$) greater than that of the males (Tables 3 and 4). This indicates that the women had higher level of adiposity than their men counterparts. However the postexercise HR, SBP, DBP, and RPP were significantly greater in men than women (Table 4). The characteristics of the three study groups were as shown in Tables 1 and 2. There were significant differences ($p < 0.05$) in the mean of height, weight, BMI, of the obese and

Table 1: Anthropometric variables in normal, overweight and obese individuals (males)

Parameters	Normal $n = 54$	Overweight ($n = 37$)	Obese ($n = 32$)
Age (years)	18.53 ± 0.95	18.39 ± 0.99	18.42 ± 0.91
Weight (kg)	57.13 ± 8.16*	67.93 ± 9.62	81.07 ± 9.87
Height (m)	1.45 ± 0.23	1.41 ± 0.20	1.46 ± 0.16
BMI (kg/m^2)	20.36 ± 1.43*#	23.20 ± 0.56#	27.89 ± 1.97

BMI, body mass index; *, significantly different from overweight group; #, significantly different from obese group.

Table 2: Anthropometric variables in normal, overweight, and obese individuals (females)

Parameters	Normal (n = 51)	Overweight (n = 40)	Obese (n = 36)
Age (years)	18.43 ± 0.85	18.32 ± 0.99	18.40 ± 0.89
Weight (kg)	57.13 ± 8.16* #	66.92 ± 8.61	80.07 ± 9.85
Height (m)	1.40 ± 0.17	1.39 ± 0.17	1.44 ± 0.14
BMI (kg/m^2)	20.39 ± 1.46* #	24.56 ± 0.59#	28.78 ± 1.86

BMI, body mass index; *, significantly different from overweight group; #, significantly different from obese group.

overweight when compared with the normal weight group for both males as well as female subjects. No significant difference in resting mean level of diastolic blood pressure was found between overweight and obese young adults in both male as well as female subjects; however significant difference was seen in systolic blood pressure of all three groups between both in men as well as women (Tables 3 and 4). The mean resting RPP was significantly higher in overweight and obese groups as compared to the normal weight group of both male and female participants. There was significant increase in RPP during exercise in all three groups of both male and female participants (Tables 3 and 4). The RPP after 5 min of recovery from exercise remained higher in these groups when compared to baseline, which was statistically significant in both male as well as female participants. Pearson's correlation coefficient showed that RPP was significantly correlated positively with BMI, in both male as well as female participants (Table 5).

Discussion

This study was conducted for showing gender-based correlation between indices of myocardial oxygen consumption, that is, RPP with BMI using dynamic exercise. RPP indirectly determine the MVo_2 and thus cardiovascular risk of subjects. Thus we can state that at rest the hearts of overweight and obese subjects consume more oxygen than those of control subjects. The higher RPP in study subjects was mainly due to increase in SBP, which indicates increase in myocardial activity and thus the MVo_2 at rest. Myocardial oxygen uptake is primarily determined by intramyocardial wall stress [i.e., the product of left ventricular (LV) pressure and volume, divided by LV wall thickness], contractility, and heart rate. Other, less important factors include external work performed by the heart, the energy necessary for activation, and the basal metabolism of the myocardium.[1,2,11,12] Thus the study shows that there is hemodynamic stress to the heart in study subjects. This study showed a highly significant increase in postexercise HR, SBP, DBP, and RPP than the preexercise values. These changes in the hemodynamic parameters were more pronounced in men as compared to women, which are similar to other studies.[17] The increased HR and SBP can be attributed to the sympathetic activation before and during the exercise. The males indicate better pressor response than the women; hence the greater increase in HR and SBP seen in men than women. Various researchers also observed greater SBP and catecholamine response to acute stress, showing a precedence of greater cardiovascular reactivity of stressors in men.[18] Several investigations have measured cardiovascular response to isometric exercise between genders, results of which are inconsistent at their best. Study conducted by Ravishankar and Madanmohan et al. on 145 subjects (105 men and 40 women) and assessed the correlation between BMI, and heart rate, systolic pressure (SP), diastolic pressure (DP), pulse pressure (PP), mean arterial pressure (MAP), rate-pressure product, endurance in the 40 mmHg test, handgrip strength (HGS), and handgrip endurance; there observations indicated that there are gender-based differences in the correlation between BMI and BP indices especially in underweight and

Table 3: Heart rate, systolic blood pressure and relative pressure product in normal, overweight, and obese female subjects

	Parameters	Normal (n = 51)	Overweight (n = 40)	Obese (n = 36)	P-value
Before exercise	HR	82.19 ± 5.15	82.28 ± 6.5	82.61 ± 7.22	NS
	SBP	102.00 ± 6.91	108.40 ± 10.88	112.14 ± 11.19	< 0.001HS
	DBP	68.37 ± 7.41	68.89 ± 3.45	70 ± 10.21	NS
	RPP	8364.53 ± 771.36* #	8856.80 ± 1154.83	9184.34 ± 1431.42	< 0.001HS
Immediately after exercise	HR	85.73 ± 6.96	88.89 ± 35.45	90.03 ± 20.66	< 0.001HS
	SBP	125.67 ± 7.63	132.36 ± 16.88	136 ± 10.27	< 0.001HS
	DBP	73.00 ± 7.59	74 ± 10.80	74 ± 3.45	NS
	RPP	10625.13 ± 1138.65* #	11616.89 ± 1638.05	12240.93 ± 1655.10	< 0.001HS
5 min after exercise	HR	83.90 ± 6.16	84.04 ± 12.90	84.07 ± 14.21	NS
	SBP	108.93 ± 8.63* #	112 ± 12.3	118 ± 5.64	< 0.001HS
	DBP	70.57 ± 4.59* #	72.29 ± 3.45	72.86 ± 6.43	NS
	RPP	8964.40 ± 1496.36	9408 ± 1823.52	9912.47 ± 1369.72	< 0.001HS

HR, heart rate; SBP, systolic blood pressure; RPP, relative pressure product; *, significantly different from overweight group; #, significantly different from obese group.

Table 4: Heart rate, systolic blood pressure and relative pressure product in normal, overweight, and obese male subjects

	Parameters	Normal (*n* = 51)	Overweight (*n* = 40)	Obese (*n* = 36)	*P*-value
Before exercise	HR	80.07 ± 7.23	80.28 ± 6.5	80.71 ± 7.22	NS
	SBP	106.07 ± 10.21* #	113.40 ± 10.88	116.14 ± 11.19	< 0.001HS
	DBP	74.57 ± 4.59	74.89 ± 3.45	75.01 ± 10.21	< 0.001HS
	RPP	8480.9 ± 771.36* #	9040.80 ± 1154.83	9280.34 ± 1431.42	< 0.001HS
Immediately after exercise	HR	124.4 ± 19.58		140.03 ± 20.66	< 0.001HS
	SBP	128.89 ± 17.76*#		146 ± 10.27	< 0.001HS
	DBP	84.34 ± 7.80	86 ± 10.80	86 ± 3.45	NS
	RPP	15872.59 ± 3613.16* #	19596.89 ± 3638.05	20440.93 ± 3655.10	< 0.001HS
5 minutes after exercise	HR	86.4 ± 13.13	90.40 ± 12.90	92.07 ± 14.21	< 0.005 S
	SBP	108.93 ± 8.63*#	116 ± 4.0	118 ± 5.64	< 0.001HS
	DBP	76.57 ± 4.59*#	78.89 ± 3.45	80 ± 6.43	< 0.001HS
	RPP	9288.40 ± 1496.36* #	10440 ± 1823.52	10856.47 ± 1369.72	< 0.001HS

HR, heart rate; SBP, systolic blood pressure; RPP, relative pressure product; *, significantly different from overweight group; #, significantly different from obese group.

overweight subjects.[14] Our results are consistently more significant than this study. Melrose found significant increase in MAP and DBP in men compared to women.[17] Mbada et al. found higher SBP in men than women and higher RPP in women than men.[6] The results are similar to the other studies that have shown increased resting RPP in obese children and adults[15,16,19,20] This MVo_2 increase could be due to the effect of obesity on cardiac remodeling and the fact that obesity increases sympathetic tone, hemodynamic load due to increase in blood volume and fatty acid metabolism in myocardium.[21,22,3,23] During submaximal exercise and immediately after exercise, all three groups showed an increase in RPP. The percentage increase in RPP was significantly higher in the overweight and obese subjects than that of normal weight subjects, which shows increased cardiac activity and thus MVo_2 in these subjects. During exercise the heart rate increased by 54% in normal weight group, 71% in over weight group and 70% in obese group whereas SBP increased by 28% in normal weight group, 31.2% in over weight group and 31.3% in obese group. Thus the increase in RPP was mainly due to increase in heart rate rather than SBP during exercise, which could be due to increase in sympathetic activity in overweight and obese subjects. The increased RPP during exercise shows that individual not only has an increased risk of heart disease but also has a very large stress on the heart with regard to oxygen delivery needs. This study also shows that the RPP remained higher in overweight and obese groups even after 5 min of recovery when compared to baseline that was statistically significant. This higher RPP after recovery was due to reduced heart rate recovery in study groups, which could be due to autonomic imbalance with reduced parasympathetic activity and increased sympathetic activity in overweight and obese groups that has been demonstrated by previous studies at rest and during exercise stress.[24,25,14] It is documented that the males have higher plasma levels of all three catecholamines out of which plasma levels of epinephrine are higher, as compared to the females.[18,26–28] This could have increased the DBP more in the men than women immediately at the end of exercise.

Table 5: Pearson's correlation coefficient between RPP and obesity indices for male and female subjects

Study group	Indices of obesity	Correlation coefficient
Female subjects (n = 127)	BMI	0.412*
Male subjects (n = 123)	BMI	0.369*

BMI, body mass index; *$p < 0.0001$.

Conclusion

This study shows highly significant increase in postexercise HR, SBP, DBP, and RPP in males compared to females that indicates men undergo significant changes in either cardiac output, total peripheral resistance, or increase in level of circulating catecholamines mainly epinephrine with many possible explanations. This study shows that increased adiposity in young adults is associated with elevated resting RPP and much higher RPP response to exercise. This indicates that there is increased MVo_2 suggesting larger hemodynamic stress to the heart. RPP changes to exercise, an indirect measure and good indicator of MVo_2, could be used for early detection of cardiac dysfunction.

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