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Gender differences in cardiovascular response to upper limb isometric exercises

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Abstract:

Background: Isometric exercise remains an important modality in patient's rehabilitation and also employed in advanced strength and endurance training programs. Numerous studies attempting to explain gender differences in cardiovascular response to isometric exercise are inconsistent at best and conflicting. The purpose of this study was to determine if the cardiovascular responses to upper limb isometric exercises differ between healthy normotensive male and female students. **Methods**: 30 normotensive males and females in the age group of 18-30 years were randomly selected. Their anthropometric variables namely height, weight and body mass index were recorded. Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Heart Rate (HR) and Rate Pressure Product (RPP) before and after three upper limb isometric exercises were used to assess the cardiovascular response. Student's paired t-test was used to compare intra group pre and post exercise cardiovascular parameters. Unpaired t-test was used to compare physical characteristics and pre and post exercise cardiovascular parameters between genders. Level of significance was set at $p<0.05$. **Results**: Post exercise cardiovascular parameters were significantly greater ($p<0.05$) than baseline values without gender bias. However the post exercise HR, SBP, DBP and RPP were significantly greater in males than females. Highly significant increase in post exercise HR, SBP, DBP and RPP was observed in males compared to females indicating that men undergo significant changes in either cardiac output, total peripheral resistance, or increase in level of circulating catecholamines mainly epinephrine with many possible explanations. Also there was significant increase in myocardial oxygen uptake which is indicated by RPP.

Key words: Cardiovascular response; DBP; Gender difference; Isometric exercises; SBP; RPP.

Introduction

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 upon the specific types of exercises undertaken, isometric or isotonic. Isometric or static exercises are characterized by change in the muscle tension with no change in the muscle length whereas isotonic or dynamic exercises exhibit change in the muscle length with tension remaining the same. Most of the muscular activities are a combination of both isometric and isotonic contractions. The isometric contractions are seen in various exercises like pushing or lifting heavy loads, where net displacement of load is not present, but the rising tension can be felt in the contracting muscles. On the other hand, isotonic contractions are seen in the activities like running, cycling, swimming etc., where change of length can be appreciated but no change of muscle tension is appreciated.

The metabolic demands of the exercising muscle increases, depending upon the intensity of the exercise and these are met with various changes in the circulatory and respiratory system. The sympathetic system plays a key role in these changes resulting in increased heart rate, systolic and diastolic blood pressure and an increased respiratory rate during the exercise. The raised systolic blood pressure is because of increased cardiac output and the raised diastolic blood pressure is due to increased peripheral resistance [1] during the exercise. All these circulatory changes result in an increased muscle blood flow to meet the demand of the muscles. In isotonic exercise, the large muscle groups contract and relax rhythmically which allows adequate blood flow to the muscle with increased SBP while in isometric exercises, the small groups of muscles remain in the contracted state throughout the exercise resulting in the compression of the blood vessels and occlusion of blood flow to active muscle. Thus it has been observed in that there is a difference in circulatory response to isometric exercises as compared to isotonic exercises. Isometric exercise has been found to increase, Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and Heart Rate (HR). Larger the muscle groups that are involved in isometric tension, greater the consequent cardiovascular responses to it [2,3]. In spite of this, isometric exercise remains an important modality in patients' rehabilitation among physical therapists. It has been reported to be effective in preventing a substantial loss of muscle mass and function during the period of recovery from an injury with joint immobilization [4]. Different forms of isometric exercises e.g. functional isometrics have been employed in some advanced training programmes [5] and also in strength and endurance training [6].

Cardiovascular response to exercise is used as major criteria in exercise prescription for both patients and healthy people. Numerous studies attempting to explain gender differences in cardiovascular response to isometric exercise are inconsistent at best and conflicting. However, it has been noted that the substantial anatomical, physiological, and morphological differences that exist between men and women may affect their exercise capacity and influence the magnitude of response to exercise [7].

The present study analyzes the changes in the cardiovascular parameters in the body that arise as a result of static or isometric exercises. There have been reported gender difference in the cardiovascular response to exercise; and this study further analyzes the differences seen in this response amongst the young male and female subjects, when subjected to isometric exercises of the upper limbs.

Objective

The purpose of this study was to determine if the cardiovascular responses to upper limb isometric exercises differ between healthy normotensive male and female students.

Materials and Methods

A total of 60 normotensive dental students (30 males and 30 females) in the age group of 18-30 years were randomly selected from Davanagere. Students 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 students were informed about the procedure and their consent obtained. Anthropometric variables of the subjects were measured in triplicate with the median value used as the criterion. The height was recorded using a stadiometer (Holtain Ltd., Crymych, Dyfed, UK) to the nearest 0.1 cm, and weight was measured by digital standing scales (Model DS-410, Seiko, Tokyo, Japan) to the nearest 0.1 kg. BMI was then calculated using the formula weight in kg / (height in metre) [2] . Hand held Dynamometer (Inco Ambala, India) was used for isometric strength exercise. Dynamometer was held at standing position with shoulder adducted and neutrally rotated and elbow in full extension. The dynamometer was held freely without support, not touching the subject's trunk. The position of the hand remained constant. The subjects were asked to put maximum force on the dynamometer thrice from both sides of the hands. The maximum value was recorded in kilograms. Sphygmomanometer: An Elkometer mercury-in-glass sphygmomanometer was used to measure blood pressure in millimetres of mercury (mm of Hg). Stethoscope: A Littman stethoscope (U.S.A) was used with the Sphygmomanometer to measure the blood pressure. The baseline cardiovascular parameters Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and Heart Rate (HR) were recorded. The participants in the upstanding position performed 3 upper limb isometric exercises for 3 minutes which comprises of two repetitions of pushing against the wall with the outstretched arms for 30 seconds each and they were instructed to exert maximal tension on the wall. Two repetitions of isometric contractions using the hand grip dynamometer was performed. The participants were in the upstanding position with the arms fully extended by the side of the body and they were instructed to exert maximal tension on the hand grip dynamometer and hold it for 30 seconds. Two repetitions of isometric contractions with the hands clasped together and brought to the manubrio-sternal level of the chest while the shoulders are 60^0-70^0 abducted (winged). The participants were instructed to maximally generate tension by pressing the opposite hands against each other in the exercise position and hold it for 30 seconds. During the exercises the participants were instructed to avoid Valsalva Manoeuvre by not holding their breath and were instructed to do rhythmic breathing in order to minimize the pressor response. On completion of the three isometric exercise bouts, the post exercise cardiovascular parameters -SBP, DBP and HR were measured.

Myocardial oxygen consumption (MVO_2) is a good indicator of the response of the coronary circulation to increased myocardial oxygen demand. The coronary blood flow (CBF) shows a linear correlation with the level of MVO_2. Thus the determinants of MVO_2 are also the determinants of CBF [8]. Direct measurement of MVO_2 is difficult in routine clinical practice but it can be easily calculated by indirect methods like stroke work, Fick's Principle, the tension time index and rate pressure product (RPP) [9]. RPP is the product of heart rate and systolic blood pressure [RPP = Systolic blood pressure (SBP) × heart rate (HR)] [10]. It is an easily measurable index, which correlates well with MVO_2 and defines the response of the coronary circulation to myocardial metabolic demands. It is a good index of MVO_2 in patients with ischemic heart disease [11]. Rate pressure product is also called Robinson Index [12]. RPP was calculated at rest and after exercise.

The study was approved by the local ethics committee.

Statistical analysis

Student's paired t-test was used to compare intra group pre and post exercise cardiovascular parameters. Unpaired t-test was used to compare physical characteristics and pre and post exercise cardiovascular parameters between genders. Level of significance was set at $p<0.05$.

Results

Post exercise cardiovascular parameters were significantly greater ($p<0.05$) than baseline values without gender bias. However the post exercise HR, SBP, DBP and RPP were significantly greater in males than females.

A total of 60 apparently healthy adults participated in this study with the mean age of males being 18.57 ± 0.68 years and that of females being 18.17 ± 1.64 years. The physical characteristics of the participants by gender are presented in Table 1. The males and females were age matched with no significant differences in their height. However, the weight and BMI of the female participants was significantly ($p <0.05$) greater than that of the males. This indicates that the females had higher level of adiposity than their male counterparts. Test comparison of the resting and post isometric exercises cardiovascular parameters in males is presented in Table 2 (Figure 1) and that of females in Table 3 (Figure 2). There were significant differences between the resting and post isometric cardiovascular parameters (HR, SBP, DBP and RPP) without gender bias. Post exercise HR, SBP, DBP and RPP were significantly different between the male and the female participants. The male participants had a higher post exercise HR, SBP, DBP and RPP level than the females (Table 4, Figure 3 and Figure 4). These results indicate that more blood is pumped by the left ventricle into the aorta in response to upper extremities isometric exercise among males than females. Also myocardial oxygen uptake and the measure of the oxygen consumption of the heart muscles of the male participants in response to upper extremities isometric exercises are higher than that of the females.

Discussion

In the present study, we compared the effect of isometric upper limb exercises on cardiovascular parameters in young males and females who had no prior endurance training. The males had more muscle mass [13, 14] as they have higher day to day activity than females. The body mass index (BMI) in females (21.45± 3.25 kg/m^2) was slightly higher than their male (20.02± 2.14 kg/m^2) counterparts and this could be attributed to the higher adiposity in the females.

This study showed a highly significant increase in post exercise HR, SBP, DBP and RPP than the pre exercise values. These changes in the hemodynamic parameters were more pronounced in males as compared to females which is similar to other studies [15]. 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 females; hence the greater increase in HR and SBP seen in males than females. Various researchers also observed greater SBP and catecholamine response to acute stress, showing a precedence of greater cardiovascular reactivity of stressors in men [16]. Several investigations have measured cardiovascular response to isometric exercise between genders, results of which are inconsistent at their best. Melrose DR found significant increase in Mean Arterial Pressure (MAP) and DBP in males compared to females. Mbada et al found higher SBP in males than females and higher RPP in females than males [17].

The mechanisms by which blood pressure and heart rate are increased in static exercise are not fully understood. It appears likely that both central and peripheral mechanisms play a role. The rapid increase seen in both blood pressure and heart rate at the onset of isometric contraction would speak for cortical irradiation [18]. During a sustained contraction, pressure and heart rate continue to rise throughout the exercise. This gradual increase of the cardiovascular response can also be ascribed to a central drive if it is assumed that the increased involvement of motor units as indicated by the electromyography is of central origin [19]. However, peripheral factors may as well be at work for the recruitment of additional motor units during the sustained contraction, which could be elicited peripherally [20]. With more muscle fibres being electrically activated, the flux of K^+ and its concentration in the interstitial fluid space would be elevated [21] thereby activating K^+ sensitive free nerve endings in the muscle [22]. Further, in sustained isometric contractions, lactate accumulation and thus osmolarity increases [23], and can act as an additional chemical drive. Regardless of the relative importance of central and peripheral regulatory mechanisms it is likely that the cardiovascular response to isometric, just as in dynamic exercise, is a function of the magnitude of the stimulus. With more motor units activated and a larger muscle mass involved in the contraction, both central and peripheral drives would be larger.

Hence isotonic exercises result in volume load on the heart while the isometric exercises result in pressure overload on the heart [24]. The myocardial oxygen consumption (MVO_2) also increases due to exercise which is reflected by increased RPP after exercise. Rate pressure product (RPP) is a major determinant of myocardial oxygen consumption hence is an important indicator of ventricular function. RPP varies with exercise such that the higher the peak RPP, the more will be myocardial oxygen consumption (MVO_2). The ability to reach higher RPP is associated with adequate coronary perfusion. The increased SBP and HR with exercise adjust myocardial supply with increased demand of the actively working cardiac muscle. The increase in HR and SBP increases the double product or rate pressure product. The RPP is increased more significantly in the males (11611.27 ± 1085.86 mm Hg beats per minute) than in the females (9052.13 ± 1138.65 mm Hg beats per minute). This increase is due to the volume overload and better pressor response of the males [8, 25]. This peak RPP reflects the better coronary perfusion of males than females to meet the increased myocardial oxygen demand during the isometric exercise.

The static exercises obliterate the blood vessels in the active exercising muscle, raising the total peripheral resistance (TPR), thus increasing the pressure load or the after load on the heart. 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 [26]. This could have increased the DBP more in the males than females immediately at the end of exercise.

Conclusion

In conclusion, this study shows highly significant increase in post exercise HR, SBP, DBP and RPP in males compared to females which 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. Also significant increase in myocardial oxygen uptake was indicated by RPP.

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Table 1: Descriptive statistics of anthropometric variables in males and females

	Males(N=30)	Females(N=30)				
Parameters	Mean	SD	Mean	SD	Mean Difference	P* Value, sig
Age (Yrs)	18.57	0.68	18.17	1.64	0.4	0.22NS
Height (cm)	157.73	14.61	154.00	20.74	3.73	0.42NS
Weight (kg)	49.02	6.20	52.13	4.69	3.11	0.03 S
BMI	20.02	2.14	21.45	3.25	1.43	0.04 S

*Student's unpaired t-test

NS-Non significant, S-Significant

Table 2: Comparison of resting and post isometric exercises cardiovascular parameters in males

	Pre-exercise			Post-exercise		
Parameters	Mean	SD	Mean	SD	Mean Difference	p* Value, sig
HR(Beats/min)	83.20	6.16	93.30	6.02	10.1	<0.001 HS
SBP(mm of Hg)	118.27	7.93	124.53	9.31	6.3	<0.001 HS
DBP(mm of Hg)	76.67	6.69	83.33	6.79	6.7	<0.001 HS
RPP	9847.87	1056.68	11611.27	1085.86	1763.4	<0.001 HS

HS-Highly significant

Table 3: Comparison of resting and post isometric exercises cardiovascular parameters in females

	Pre-exercise		Post-exercise			
Parameters	Mean	SD	Mean	SD	Mean Difference	P* Value, sig
HR(Beats/min)	80.07	7.23	85.73	6.96	5.7	<0.001 HS
SBP(mm Hg)	102.00	6.91	105.67	7.63	3.7	<0.001 HS
DBP(mm Hg)	69.47	7.41	73.00	7.59	3.5	<0.001 HS
RPP	8202.53	990.21	9052.13	1138.65	849.6	<0.001 HS

HS-Highly significant

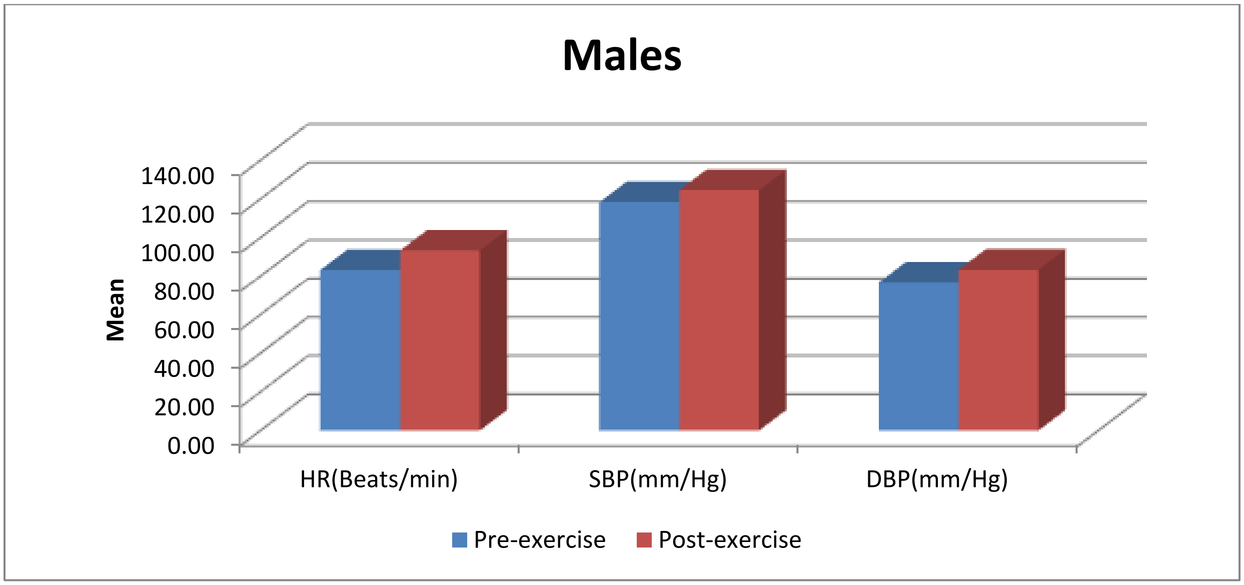

Figure 1: Graphical representation of pre-exercise and post-exercise cardiovascular parameters in males

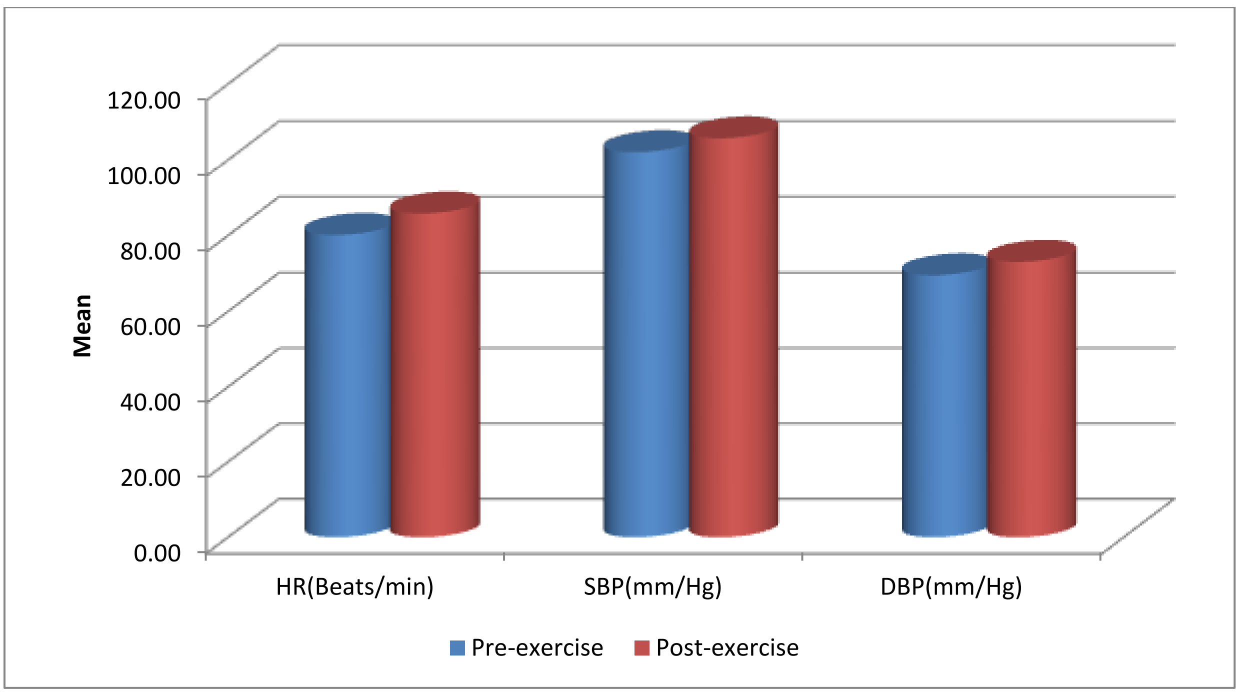

Figure 2: Graphical representation of pre-exercise and post-exercise cardiovascular parameters in females

Table 4: Comparison of post exercise parameters by gender

Intergroup comparison: Post exercise						
	Males		Females			
Parameters	Mean	SD	Mean	SD	Mean Difference	p* value, sig
HR(Beats/min)	10.10	3.90	5.67	2.47	4.4	<0.001 HS
SBP(mm/Hg)	6.27	6.07	3.67	2.68	2.6	0.04 S
DBP(mm/Hg)	6.67	1.92	3.53	2.01	3.1	<0.001 HS
RPP	1763.40	772.34	849.60	487.69	913.8	<0.001 HS

HS-Highly Significant, S-significant

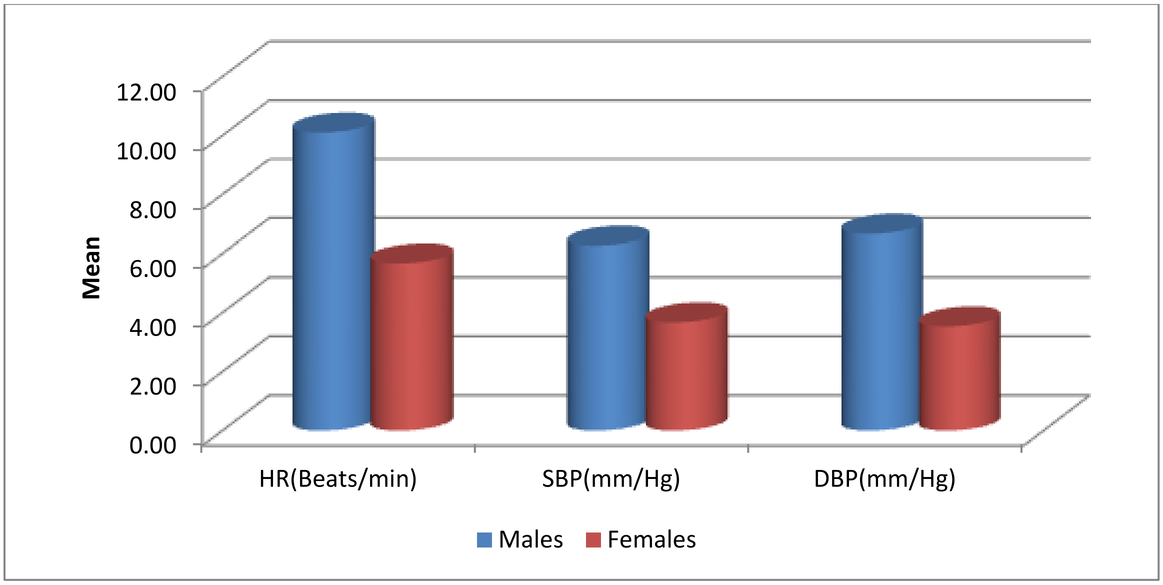

Figure 3: Graphical representation of post-exercise cardiovascular parameters by gender

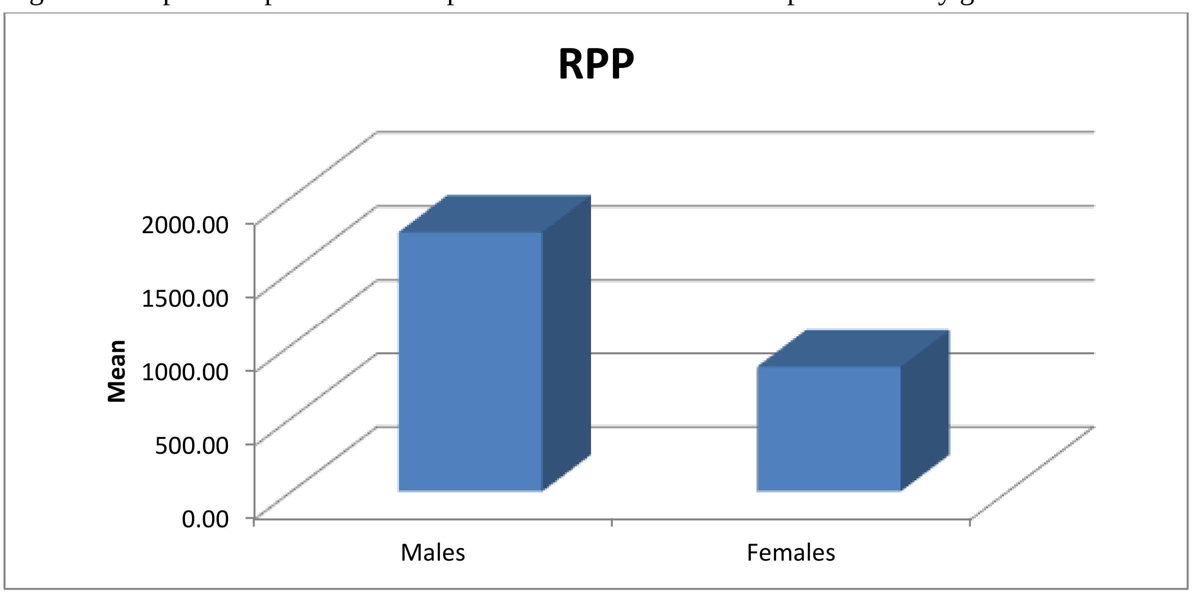

Figure 4: Graphical representation of Rate Pressure Product in males and females.