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Rate Pressure Product as a Determinant of Physical Fitness in Normal Young Adults

Prema Sembulingam[1], Sembulingam K[2], Saraswathi Ilango[3], Sridevi G[4],

1. Professor of Physiology & Head of R & D. Madha Medical College & Research Institute, Kundrathur Main Road, Thandalam near Porur, Chennai – 600 122, Tamil Nadu, India.
2. Professor of Physiology and Vice Principal, Madha Medical College & Research Institute, Kundrathur Main Road, Thandalam near Porur, Chennai – 600 122, Tamil Nadu, India.
3. Tutor in Physiology, Madha Medical College & Research Institute, Kundrathur Main Road, Thandalam near Porur, Chennai – 600 122, Tamil Nadu, India.
4. Lecturer in Physiology, Sathyabama University Dental College & Hospital, Jeppiar Nagar, Rajiv Gandhi Salai, Solinganallur, Old Mahabalipuram Road, Chennai – 600 199, Tamil Nadu, India.

Abstract: *Rate Pressure Product (RPP) is a valuable marker of cardiac function.It is the product of heart rate (HR) and systolic blood pressure (SBP) (HR x SBP/1000). RPP up to 12 at rest and up to 22 in stressed conditions is considered as normal. This study deals with RPP evaluation in60 young normal subjects of 18 to 22 years old (30 males and 30 females).HR and SBP were recorded before and after 5 min of mental stress (mental arithmetic) and physical stress (cycling) from which RPP was calculated.RPP increased significantly after mental stress in both the genders (males (M) $p< 0.0001$ and females (F) $p< 0.0005$). But there was no gender difference in the level of increase. After physical stress also RPP increased in males significantly ($p<0.0004$)and in females non-significantly ($p<0.143$).Determination of RPP is the best non-invasive and time sparing method of assessing the functional status of heart. It is controlled by autonomic nervous system (ANS) through HR and SBP. Increase in RPP under stressed condition implies the normal buffering function of ANSand good coronary perfusion. In the present study, RPP increased significantly in males and non-significantly in females after physical stress, implying that ANS buffering function is better in males than in females. We conclude that RPP is a good index to assess cardiovascular competency in stress which may help to determine the intensity and duration of exercise in developing physical fitness and in patient-care without overloading the heart.*

Keywords:*Autonomic nervous system, Heart rate, Mental stress, Physical stress, Rate pressure product, Systolic blood pressure*

I. Introduction

Rate pressure product (RPP) is a valuable marker of the oxygen requirement in the heart in a given condition[1]. It reflects the internal myocardial work performed by the beating heart whereas the performance of the external myocardial work is represented by the stages of exercise[2, 3]. RPP is defined as the product of resting heart rate (RHR) and systolic blood pressure (SBP) [4]and it is expressed as RPP = SBP × HR/1000 [5]. Heart, being a muscular organ, its regular functioning needs steady supply of oxygen and nutrients; if these supply are deficient, there is all chances of heart failure to occur [2]. The importance of this is more applicablein stressed conditions than in resting conditions...In this contest, RPP is useful in determining the physical fitness of a person in rest as well as in stressed conditions. Actually, the physical fitness of a person depends upon his blood pressure (BP) and heart rate (HR). A person is considered physically fit if his RHR ranges between 65 to 70 beats per minute (bpm) and blood pressure (BP)is 120/80 mm Hg (SBP - 120 mmHg and diastolic blood pressure (DBP)-80 mm Hg). Such persons are clinically safe and may not be affected much by stress of any kind – either physical or mental. However, in a person with deconditioned physical fitness with higher RHR (85/min) and BP (140/90 mm Hg), the impact of stress may create havoc, sometimes leading to cardiac arrest also [1, 2].

Thus, the assessment of physical fitnessmay serve as a simple and reliable method to avoid the stress-induced cardiovascular problems. Fortunately this can be done easily by finding out the stress-influenced RPP through the HR and BP changes. Under resting conditions, safer RPP should range between 7.00 and 9.00. According to Sarnoff (1958) and Fletcher (1979) et al, any total value of RPP more than 10,000 (10.00) is a clear indicator of increased risk for heart disease [6, 7].Stress in any form – either mental stress in the form of fear, anxiety, harassment etc or physical stress in the form of manual work, exercise etc affect the cardiovascular system. Sometimes mental stress may affect the functional systems, especially cardiovascular system - more than the physical stress. If the mental stress is accompanied by the harassment, the effect may be aggravated. In the present study, we probed into the physical fitness of apparently healthy young individuals and tried to validate the importance of RPP in determining the cardiovascular stress-tolerance and explore the gender difference in this respect.

II. Materials And Methods

The study was done in Madha Medical College & Research Institute and Sathyabama Dental College & Hospital, Chennai. 60 students (30 males and 30 femalesin the age group of 18 to 22 years participated in the study. Institutional Ethical committees of the respective colleges approved the study.Written informed consent was obtained from the participants after making them to understand the importance of the project, their role in the project and the procedural part of the project. Utmost care was taken to exclude the students who had any cardiorespiratory, neurological and endocrine problems or those who were on medication for some reason or the other and also smokers, alcoholics and drug users. Regular exercising individuals, yoga practitioners ,sports persons and athletes were also excluded from the study.

All the subjects were instructed to report in Physiology Department of respective Institutions. Anthropometric variables were recorded. Body mass index (BMI), basal metabolic rate (BMR) and fat percentage (F %) was noted by using the Body Fat Monitor (OMRON). Basal measures of SBP (BSBP), and heart rate (BHR) were recorded by using automatic BP monitor (OMRON). Then all the participants were subjected for mental and physical stress. After mental stress, stress-induced changes in SBP and HR were recorded. After 20 minutes of rest, physical stress was induced by cycling.

2. 1. Procedure for stress

2. 1. 1. Mental stress: Participants wereinstructed to perform a challenging arithmetic task of subtracting 13 from a 4 digit number on a paper for 5 minutes. During the performance, they were harassed verbally for faster and correct performance. Immediately after five minutes, the papers were collected and the variables were recorded.

2. 1. 2. Physical stress: Participants were rested for20 minutes after mental stressand BSBP and BHR were recorded again. Then, the participants were instructed to do cycling in a bicycle ergometer against the load of 2 kg with pedaling speed of 16 revolutions per minute (RPM) for the same duration of 5 minutes. Immediately after this, SBP and HR were recorded again.

From the values obtained, RPP was calculated by using the formula HR X SBP.

Data were entered in MS Excel spread sheet and analysis was done by using student't test. Significance level was fixed at $p<0.05$.

III. Results

In the tables, values were expressed as mean ± SEM. SBP was expressed in mmHG and HR was expressed in beats per minute. Numbers in the parenthesis indicate the total number of subjects. Significance was indicated by *

3. 1. Mental Stress:

In males, RPP showed significant increase ($p < 0.0001$) after mental stress. This increase in RPP was because of the significant increase in SBP ($p< 0.0007$) and HR (0.0003).

In females also, RPP showed significant increase after mental stress ($p < 0.0005$) and this increase was because of the significant increase in SBP ($p< 0.002$) and HR ($p<0.0006$)(Table 1)

Table 1. Effect of Mental Stress (MS) on SBP, HR and RPP in males and females

Gender	Variable	Before MS	After MS	Significance
Male (30)	SBP	121.90 ± 2.03	129.57 ± 2.45	p<0.0007*
	HR	82.33 ± 2.73	90.60 ± 2.43	p<0.0003*
	RPP	10.10 ± 0.45	11.78 ± 0.42	p<0.0001*
Female (30)	SBP	110.37 ± 1.69	118.63 ± 2.85	p<0.002*
	HR	85.43 ± 5.48	95.70 ± 3.41	p<0.0006*
	RPP	9.47 ± 0.36	11.54 ± 0.64	p<0.0005*

MS – Mental stress

3. 2. Physical Stress:

In males, there was significant increase in RPP ($p < 0.0004$) after physical stress which was due to the significant increase in SBP ($p < 0.0002$) and HR ($p< 0.002$).

In females, RPP did not show any significant change ($p< 0.143$) after physical stress; however, there was significant increase in SBP ($p < 0.\ 003$) and HR ($p < 0.0006$) (Table 2).

3. 3. Gender difference in the response to mental and physical stress:

There was no significant difference in all the three variables between males and females. However, females showed non-significant increase in all the variables after both mental and physical stress (Table 3).

Table 2. Effect of physical Stress on SBP, HR and RPP in males and females

Gender	Variable	Before Phy S	After Phy S	Significance
Male (30)	SBP	118.77 ± 1.81	141.90 ± 1.83	p<0.0002*
	HR	81.67 ± 1.39	126.27 ± 2.88	p<0.002*
	RPP	9.70 ± 0.35	17.94 ± 0.61	p<0.0004*
Female (30)	SBP	109.27 ± 1.85	132.53 ± 1.91	p<0.003*
	HR	84.20 ± 2.98	132.80 ± 2.87	p<0.0006*
	RPP	9.26 ± 0.38	17.60 ± 0.44	p<0.143

Phy S – Physical stress

Table 3. Gender difference in response to mental and physical stress on SBP, HR and RPP

Type of stress	Variable	Difference between before and after stress (mean ± SEM)		Significance p <
		Males	Females	
Mental Stress	SBP	- 7.67 ± 2.03	- 10.27 ± 2.66	0.851
	HR	- 8.27 ± 2.03	- 10.27 ± 2.66	0.553
	RPP	- 1.68 ± 0.38	- 2.07 ± 0.53	0.547
Physical Stress	SBP	- 23.20 ± 1.87	- 23.27 ± 1.74	0.979
	HR	- 44.60 ± 1.4	- 48.60 ± 3.10	0.227
	RPP	- 8.25 ± 0.31	- 8.33 ± 0.41	0.866

3. 4. Subject percentage and the range of RPP

We formulated a classification depending upon the range of RPP values as shown in Table 4 (based on 6, 7, 9, 10)

Table 4. Different zones of RPP based on its range

Range of RPP	Zone of RPP
Up to 12	Normal zone
Above 12 up to 17	Risk zone
Above 17 up to 21	Danger zone
Above 21	Very danger zone

3.5. Percentagewise-Impact of Mental stress in Males:

83.33% (25) of the male subjects were well within the normal zone of RPP and 16.66% (5) of them were in the risk zone before subjected for mental stress. After mental stress, only 50% (15) of them remained in the normal zone whereas another 50% (15) of them moved to the risk zone..However, none of them were in the danger zone or very danger zone (Table 5)

3.6. Percentagewise-Impact of Mental stress in Females:

86.66% (26) of the females were in the normal zone of RPP and 13.33% (4) of them were in the risk zone before subjected for mental stress. After mental stress, only 53.33% (16) of them remained in the normal zone whereas 40% (12) of them moved to the risk zone, 3.33% (1) of them were in the danger zone and another 3.33% (1))of them were pushed to very danger zone (Table 5).

3.7. Percentagewise-Impact of Physical stress in males:

86.66% (26) of the males were in the normal zone and 13.33% (4) of them were in the risk zone before subjected to physical stress but none of them were either in the danger zone or very danger zone. After the physical stress, none of them remained in the normal zone. 36.66% (11) of them entered into the risk zone, 50% (15) of them moved to the danger zone and 13.33% (4) of them were found in the very danger zone (Table 6)

Table 5. Gender difference in percentage change in RPP after mental stress

RPP range	Male (30)				Female (30)			
	Before mental stress		After mental stress		Before mental stress		After mental stress	
	No	%	No	%	No	%	No	%
Up to 12 Normal zone	25	83.33	15	50	26	86.66	16	53.33
Above 12 till 17 Risk zone	5	16.66	15	50	4	13.33	12	40
Above 17 till 21 Danger zone	Nil	Nil	Nil	Nil	Nil	Nil	1	3.33
Above 21 Very danger zone	Nil	Nil	Nil	Nil	Nil	Nil	1	3.33
Total	30	100 (99.99)	30	100	30	100 (99.99)	30	100 (99.99)

3.7. Percentagewise-Impact of Physical stress in males:

86.66% (26) of the males were in the normal zone and 13.33% (4)of them were in the risk zone before subjected to physical stress but none of them were either in the danger zone or very danger zone. After the physical stress, none of them remained in the normal zone. 36.66% (11)of them entered into the risk zone, 50% (15) of them moved to the danger zone and 13.33% (4) of them were found in the very danger zone (Table 6)

3. 7.Percentagewise-Impact of Physical stress in females:

Before physical stress, 90% (27)of them were in the normal zone and 10% (3) of them were in the risk zone. But none of them were in the danger or very danger zone. After physical stress, none of them remained in the normal zone. 40% (12)of them moved to the risk zone, 53.33% (16) of them were in the danger zone and 6.66% (2) of them moved to the very danger zone (Table 6)

Table 6.Gender difference in percentage change in RPP after mental stress

RPP range	Male (30)				Female (30)			
	Before physical stress		After Physical stress		Before physical stress		After physical stress	
	No	%	No	%	No	%	No	%
Up to 12 Normal zone	26	86.66	Nil	Nil	27	90	Nil	Nil
Above 12 till 17 Risk zone	4	13.33	11	36.66	3	10	12	40
Above 17 till 21 Danger zone	Nil	Nil	15	50	0	0	16	53.33
Above 21 Very danger zone	Nil	Nil	4	13.33	0	0	2	6.66
Total	30	100	30	100	30	100	30	100

IV. Discussion

Usually, invasive methods are used to determine the oxygen consumption (VO_{2max}) of an organ by collecting arterial and venous blood and subjecting it for blood gas analysis which is a tedious,time consuming and risky process. But determination of RPP is a very handy non-invasive method of knowing $VO_{2max}$and it is a simple, reliable and reproducible process serving the same purpose as that of invasive method.

RPP is not only an index of O_2 consumption by the heart but also an important indicator of ventricular functional status. Determination of cardiac oxygen consumption becomes important while training an athlete or in monitoring the level of exercise to be done by various groups of persons like obese persons, cardiac patients and diabetic patients and also in normal persons who are health conscious [4]. Whoever it may be, exercise should be done within limits. Otherwise, it will have an adverse effect on the body. In fact, if the cardiac muscle is over-worked beyond ‘limit’, it may lead to the development of angina. That ‘limit’ can be determined by calculatingRPP[8].

This ‘limit’ cannot be predetermined. Under resting conditions, safer RPP should range between 7.00 and 9.00. Any total value of RPP more than 10,000 (10.00) is a clear indicator of increased risk for heart disease [6, 7]. According to SangeethaNagpal et al., most of the normal individuals develop a RPP of 20 to 35 mm Hg × beats/min × 10–3 without any discomfort which is an indication of normal ventricular function. At the same time, low RPP value suggests the restricted coronary blood supply with inadequate ventricular function. Maximum RPP is reported to range from 10th percentile value of 25,000 to a 90th percentile of 40,000 [9].However, RPP of more than 22 is considered to be a prelude of myocardial ischemia and angina [7].According to White WB, RPP of 12 or below 12 with the HR of 60 to 120 bpm and SBP of 100 to 140 mm Hg is considered to be normal without any existing or future risk of cardiovascular complications in normal individuals [10].

Putting together all these statements, we formatted a table for normal individuals depending upon the range of RPP values as shown in Table 4. Accordingly, we found the basal RPP well within normal limits in both the genders. However, it is slightly less in males (8.91 ± 1.83) than in females (9.30 ± 2.11). Even the level of stress-induced increase in RPP (mental and physical stress) is less in males than in females (non-significant). Though the difference is not statistically significant, yet it has got its own functional significance because lesser RPP is an indicator of more PSN activity and increased parasympathetic tone which is believed to be cardio-protective [11]. Accordingly, males seem to be safer with more parasympathetically mediated cardio-protection than the females. The non-significant values may be because of the less number of subjects. Though 30 subjects in each gender is substantial for statistical significant, still it may be effective if the results can be authenticated by including larger group of subjects. We reported in our earlier study also that males have less RPP with lower BMI and HR which gives armour against stress-induced cardiovascular problems [12].

Now coming to the implication of stress-induced changes in RPP in the present study, significant increasein SBP and HR with an equally significant increase in RPPafter mental stress shows that autonomic buffering action is well set in these subjects (Table 1). These factors facilitate the coronary perfusion and O_2 supply to and O_2 consumption by the myocardium. So, these youngsters could tolerate the impact of acute mental stress without any cardiovascular havoc [13, 14, 15, 16, 17]. However, some of the clinical studies revealed thatin patients suffering from chronic heart failure, hypertension, coronary heart disease etc, ANS buffering action is lost and their cardio-protection is at stake [18, 15, 17].

Physical exercise also increases RPP by increasing HR and SBP. It is attributed to stress-response of the body through elevated sympathetic activity and reduced parasympathetic activity [18, 19, 20].The individual components of RPP (SBP and HR) play an important role in determining O_2 supply to the heart and management of ischemic heart disease, especially in stress. If SBP alone increases without altering the HR, it favours the myocardial oxygenation than an increase in HR along with SBP (18, 9). In our present study, both the genders showed significant increase in HR along with SBP after mental and physical stress which was adequate to withstand the stress consequences; and the subjects, being healthy and young could tolerate the cardiovascular stress without discomfort. (Table 1, 2).

RPP is not only a major determinant of myocardial oxygen consumption ((MVO_2) but also an important indicator of ventricular function; and the accurate myocardial oxygen demand and the exact myocardial workload during exercise are reflected by the value of peak RPP (PRPP). AsPRPP and MVO_2 go hand in hand, an adequate coronary perfusion is necessary to maintain these two. Thus decrease in PRPP is an indicator of significant compromise of coronary perfusion and decreased left ventricular function[18]. Fortunately, all the subjects in our present study seem to be having good coronary perfusion and normal ventricular function as reflected by the elevated RPP after exercise.

V. Conclusion

The results of the present study reveal that RPP can be considered as an index to assess the sufficiency of coronary perfusion and the competence of myocardium in deriving the required O_2 (MVO_2) at rest and under stress. This may help the trainees, trainers, physicians and health-conscious subjects to determine the intensity and duration of exercise in developing physical fitness and patient-care without overloading the heart.

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