Influence of training on Myocardial Oxygen Consumption (MVO_2) and electrical activity of the heart : A Comparative study.

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Abstracts - Rate Pressure Product (RPP) is a valuable marker of the oxygen requirement in the heart in a given condition. It used to measure the stress put on the cardiac muscle based on the number of times it needs to beat per minute (Heart Rate (HR) and the arterial blood pressure that it is pumping against (Systolic Blood Pressure (SBP)). This research was focused on the myocardial oxygen demand and electrical activities of the heart between trained swimmers and table tennis players (both male and female) and to find out the relationship between them. Height, Weight, Body Fat Percentage, Blood Pressure (BP), HR and RPP were estimated using standard method. Automatic 12 leads electrocardiogram machine was used to record electrocardiographic changes of each player. HR is most important parameter in sports science which shows significant differences in both cases but QT Interval(ventricular depolarization and repolarization time) only shows significant differences between female players group.RPP is negative significantly correlated with QT Interval($p<0.05$) and positive significantly correlated with HR($p<0.01$) and Corrected QT Interval (QTc) ($p<0.05$).During ventricular systole (depolarization) heart contracts more forcefully and requires energy(supplied by oxygen) but during ventricular diastole (repolarization) heart relaxes, means it is not in stressed condition and it indicates myocardial oxygen demand will be low. In conclusion, longer will be the ventricular repolarization time less will be the myocardial stress or oxygen demand.

Keywords - Myocardial oxygen consumption, Electrocardiograph, Swimming, Table Tennis.

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1 INTRODUCTION

Proper training session needed for the betterment of specific sports activity [9].Sports training is a process, which is developed by planning and it is controlled for achieving a goal, changes in complex sports motor performance, ability to act and behaviour are made through measures of content, methods and organization[18]**.** Sports training mainly based on scientific knowledge and it is a pedagogical process of sports perfection which through systematic effect on psycho-physical performance ability and performance readiness aims at leading the sportsman to high and the highest performance. Though active and conscious interaction with the given demands in sports training, the sportsman's personality develops according to the norms and standards of socialist society [11]. Successful athletes competing in different sports within different competitive classes show similarities in their body dimension and body constitution, although this similarity varies greatly among sports [3]. Rate pressure product (RPP), it is a term used in cardiology, as well as exercise physiology, to measure the workload—or oxygen demand—of the heart, and reflects hemodynamic stress. RPP can also be determined at the recommended level of safe exercise—what can be called the "target heart rate" or "target zone." So it can be say that it is an index of myocardial oxygen consumption during exercise [6]. Regular physical training in junior athletes was associated with a high prevalence of bradycardia, repolarization, and voltage criteria for atrial enlargement and ventricular hypertrophy [19]. The normal physiologic changes occurring in athletic hearts are not completely understood. A spectrum of ECG patterns in the junior athlete should be useful in distinguishing a normal athlete's heart from the pathological state [19].In addition, the ECG was known to exhibit a low positive predictive value in low prevalence populations, leading to the suggestion that the ECG has low specificity in athletes when using standard ECG criteria [22]. These are very often poor indicators of the presence of left ventricular hypertrophy but nevertheless this was found to be more common in the athletic population [19]. Moreover, in previously published studies, broad criteria for interpretation have been used, and recommended, without considering, age, gender, sports discipline, and ethnicity [4]. Partly for these reasons, the American Heart Association (AHA) has not supported the addition of the ECG to there-participation exercise (PPE) of American athletes [20]. A prolonged QT time was one of the most important electrocardiographic abnormalities & an important cause of sudden cardiac death [17]. Because of QT time was generally longer in females, they are more often affected by arrhythmia due to a prolong QT interval than men [25]. Over the last decades, research has mainly revealed insights in the genetic pathogeneses of a prolong QT time [10]. Thus the focus on this study was to correlate the rate pressure product and electrical status of heart to assess the relationship of myocardial oxygen demand and electrical activities of trained male and female players.

2 AIMS AND OBJECTIVES

The objective of this research was focused on the myocardial oxygen demand and electrical activities of the heart between two types of sports discipline, both male and female trained players and to find out the relationship between them.

3 METHOD

In this study trained players [Swimmer male (n=19 and Swimmer female (n=6), Table tennis player male (n=15) and Table tennis player female (n=14)] were participated as subjects. Individual NFHS (National Standard of Living Index) and SCAT (Sports Competition Anxiety Test) were carried out in each subject. Participant table tennis players of this project were from Hooghly District, West Bengal, India and at least participated in District, State or National level competition. All measurements were conducted at club premises in the month of February, 2015. Prior permission was obtained from Institutional Ethical Committee (SCHEC/01/2015). All participants and their parents were informed about the purpose and procedures of this study.
The following measurement had been done in each swimmers and table tennis players:-

3.1 Anthropometric Measurements

Anthropometric measurements of all players were done on the same day to avoid technical error. Measurements were done by the Level 1and 2 Anthropometrists accredited by International society for advancement of Kinanthropometry (ISAK) [14] with the help of ISAK manual [15].

Stature (cm) was the perpendicular distance between the transverse planes of the Vertex and the inferior aspect of the feet. It was measured by Stadiometer (minimum range of measurement 60cm to 220cm).
Body mass (kg) was measured with an electronic weighing machine.

3.2 Body Fat % and Total Fat Content (kg)

From the four different skin fold thickness the Body Density (kg/mm^3) was measured using the Durnin & Womersley's (1974) generalized equation for body density and the Total Body Fat Percentage (%) was calculated using the equation derived by Brozek et al. (1963) and Siri (1956).
Equations for calculating Body Density (kg/mm^3), Total Fat percentage (%) are given below.
Body Density
for Male =1.1620-0.0630log (Biceps + Triceps + Subscapular + Supraspinale) for 17-19 years for Female = 1.1549-0.0678log (Biceps + Triceps + Subscapular + Supraspinale) for 16-19 years
Total Body Fat Percentage (%) = ((4.45/Body density)-4.142) x 100

3.3 Resting Heart Rate (beats / min)

It was measured after 30 minutes of rest in sitting posture by palpatory method on the radial artery of the left arm by keeping that arm to rest upon a horizontal plane.

3.4 Blood Pressure (mm Hg)

Systolic Blood Pressure (mm Hg) and Diastolic Blood Pressure (mm Hg) for each trained players were recorded in sitting posture with the help of Standard Electronic Sphygmomanometer. Rate Pressure Product is calculated with the help of Systolic Blood Pressure. The equation is given below.

Rate Pressure Product: (Resting Heart Rate x Systolic Blood Pressure)

3.5 ECG Parameters

ECG for each player was recorded in the supine position on the exam table. BPL Cardiart 6208R automatic 12 leads machine was used in the purpose in automatic mode. It contains software which provides values of durations, intervals, and QTc automatically. In this software the QT interval was measured in three leads on each of the 12 lead ECG; II, aVF and V5.
If any one or all of the three leads were immeasurable, alternate leads (V3, V4, I, aVR, aVL, V1 and V2) were used for measuring the QT interval. As QT interval was depend on Heart Rate, the measured QT intervals are usually corrected by using the most widely method of correction proposed by Bazett (Bazett's Formula = QT interval / square root of RR interval) [1] but in this study QTc values were calculated by the (BPL Cardiart 6208R automatic 12 leads machine) in-build software of the machine, using Bazett's formula.

3.6 Statistical Analysis

Statistical calculation was done with the help of SPSS package version 16. Mean Values and Standard Deviations of each mentioned parameters of both players in case of sexes were calculated. Two tail T-test was done to compare each of the parameters of both players (swimmer male with table tennis male players and swimmer female with table tennis female players). Probability of error due to random sampling was rejected at the level of $p<0.05$ and $p<0.01$. The correlation (r) is done with one parameter with another by Pearson's Correlation Coefficient (r).

4 RESULT

The Mean Values and Standard Deviation with the Level of Significance of Age (years), Height (cm), Weight (kg), Total Body Fat Percentage (%), Heart Rate (beats/min), Systolic

ISSN 2229-5518

Blood Pressure (mm Hg), Diastolic Blood Pressure (mm Hg), Rate pressure Product, P (ms), PR (ms), QT (ms), QTc (ms) of trained male and female players are shown in **Table 1 & 2**. Significant values are shown in **Fig. 1, 2 & 3**.

Table 1. Mean ± SD values with level of significance of trained male swimmers and table tennis players. (n= sample size, p=probability of error due to random sampling, NS = not significant).

Parameters	Swimmers (n=19)	Table Tennis Players (n=15)	Level of significance
Age (years)	12.65±2.37	13.29±1.86	NS
Height (cm)	153.88±13.37	155.82±14.24	NS
Weight (kg)	45.60±10.59	47.64±10.31	NS
Body Fat Percentage	14.15±5.81	16.40±4.93	NS
Heart Rate (beats/min)	68.3±15.30	**80.07±13.15**	$p < 0.05$
Systolic Blood Pressure (mm Hg)	117.00±10.30	114.29±13.52	NS
Diastolic blood pressure (mm Hg)	64.80±8.04	65.14±5.53	NS
Rate Pressure Product	7957.8±1736.79	9218.7±2195.22	NS
P (ms)	98.90±5.29	100.00±6.03	NS
PR (ms)	129.60±9.92	124.86±11.86	NS
QT (ms)	387.20±28.38	367.43±31.78	NS
QTc (ms)	408.80±25.82	422.43±44.91	NS

Table 2. Mean ± SD values with level of significance of trained male swimmers and table tennis players. (n= sample size, p=probability of error due to random sampling, NS = not significant).

Parameters	Swimmers (n=6)	Table Tennis Players (n=14)	Level of significance
Age (years)	11.83±1.60	14±3.31	NS
Height (cm)	147.90±4.78	149.61±8.1	NS
Weight (kg)	44.33±5.28	48.07±19.92	NS
Body Fat Percentage	23.63±3.66	23.61±8.80	NS
Heart Rate (beats/min)	77.00±9.01	**91.64±14.07**	$p < 0.05$
Systolic Blood Pressure (mm Hg)	118.50±8.17	115.14±13.30	NS
Diastolic blood pressure (mm Hg)	67.5±5.68	64.07±11.03	NS
Rate Pressure Product	9140.00±1391.21	10537.29±1912.47	NS

P (ms)	96.33±4.08	101.14±7.87	NS
PR (ms)	127.68±17.32	134.86±16.49	NS
QT (ms)	**374.67±20.62**	351.43±15.95	P < 0.05
QTc (ms)	423.50±30.14	432.07±20.59	NS

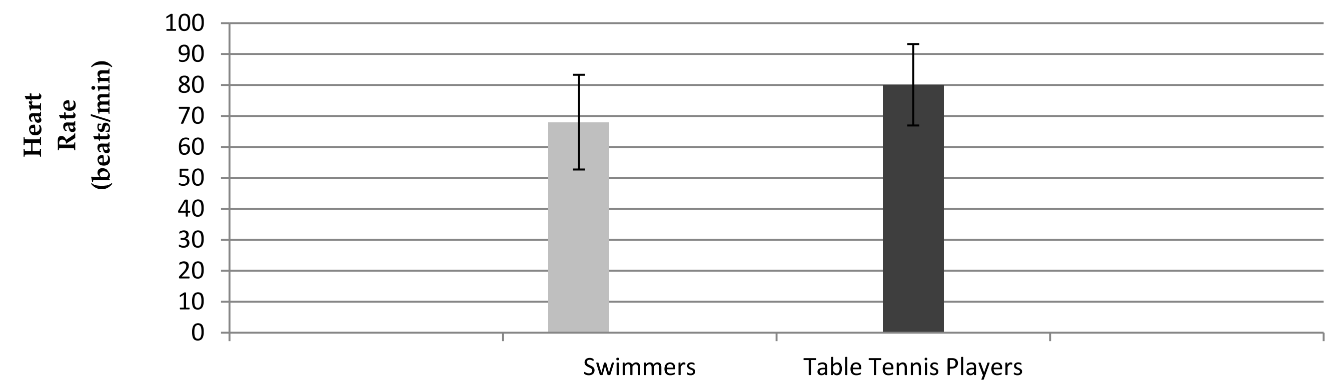

Fig. 1. Mean±SD values of Heart Rate of male swimmers and table tennis players

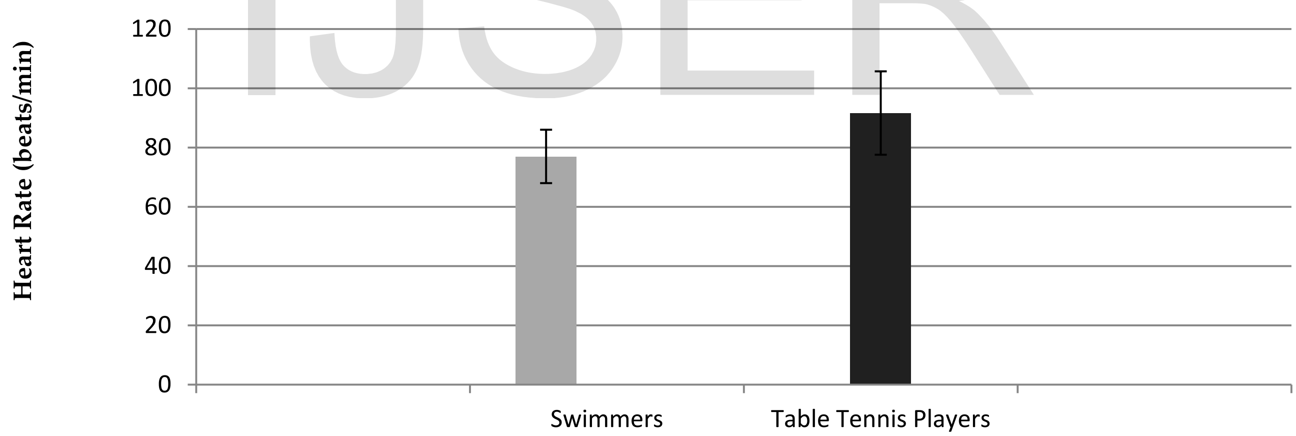

Fig. 1. Mean±SD values of Heart Rate of female swimmers and table tennis players

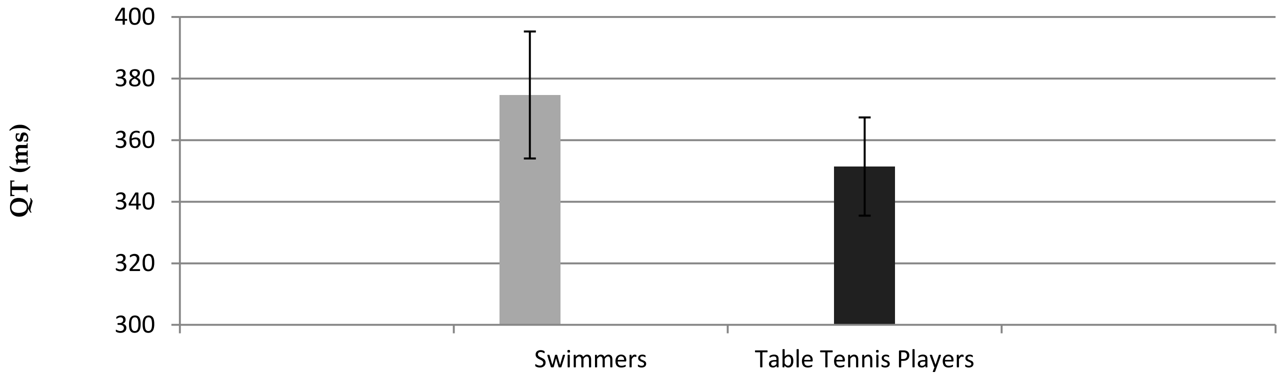

Fig. 1. Mean±SD values of QT Interval of female swimmers and table tennis players

Table 3. Comparison of the Correlation values of different parameters of trained male swimmers. (n= sample size, p=probability of error due to random sampling, NS = not significant, *=p<0.05, **=p<0.01).

	SYS	DIAS	HR	P	PR	QT	QTC	HEIGHT	WEIGHT	BODYFAT	RPP
AGE	0.272	0.292	-0.086	0.329	-0.060	0.269	**0.458***	**0.554***	0.355	**0.452***	0.030
SYS		-0.095	-0.223	**.444***	0.101	0.048	-0.311	**.463***	0.431	-0.195	0.174
DIAS			-0.071	0.064	-0.08	0.062	-0.021	0.135	0.181	-0.061	-0.11
HR				0.192	0.165	**-.740****	**.600****	0.238	-0.3	-0.086	**.920****
P					0.087	-0.194	-0.066	**.650****	0.413	-0.052	0.366
PR						-0.318	-0.072	-0.034	0.048	0.08	0.207
QT							0.07	-0.285	-0.011	-0.015	**-.727****
QTC								-0.062	**-.496***	-0.112	**.489***
HEIGHT									**.631****	-0.368	0.425
WEIGHT										0.177	-0.133
BODYFAT											-0.159

Table 4. Comparison of the Correlation values of different parameters of trained male table tennis players. (n= sample size, p=probability of error due to random sampling, NS = not significant, *=p<0.05, **=p<0.01).

	SYS	DIAS	HR	P	PR	QT	QTC	HEIGHT	WEIGHT	BODY FAT	RPP
AGE	-0.252	-0.132	**-0.571***	-0.137	-0.368	0.019	0.419	**-0.562***	-0.312	**-0.493***	0.523
SYS		**.615***	0.41	0.312	0.434	-0.4	-0.027	**.846****	**.819****	-0.259	**.747****
DIAS			0.509	-0.042	0.446	-0.455	-0.016	0.296	0.422	0.12	**.661***
HR				0.101	**.601***	-0.286	0.519	0.391	0.186	-0.412	**.911****
P					0.22	0.031	0.084	0.5	0.367	**-.571***	0.229
PR						-0.292	0.222	0.462	0.228	-0.224	**.627***
QT							**.667****	-0.143	-0.374	-0.373	-0.407
QTC								0.185	-0.18	-.631*	0.345
HEIGHT									**.843****	-0.487	**.659***
WEIGHT										-0.039	0.51
BODY FAT											-0.41

ISSN 2229-5518

Table 5. Comparison of the Correlation values of different parameters of trained female swimmers. (n= sample size, p=probability of error due to random sampling, NS = not significant, *=p<0.05, **=p<0.01).

	SYS	DIAS	HR	P	PR	QT	QTC	HEIGHT	WEIGHT	BODY FAT	RPP
AGE	-0.665	-0.340	-0.139	-0.234	-0.204	0.125	0.010	0.021	-0.394	-0.045	0.396
SYS		0.752	0.253	-0.15	0.352	-0.496	-0.199	0.538	0.501	-0.466	0.64
DIAS			0.57	0.284	-0.071	-0.317	0.21	**.926****	**.860***	-0.089	0.778
HR				0.25	-0.141	-0.263	0.623	0.48	0.454	0.276	**.905***
P					-0.292	0.168	0.317	0.261	0.718	**.873***	0.119
PR						**-.878***	**-.830***	-0.114	-0.112	-0.151	0.05
QT							0.59	-0.31	-0.201	0.101	-0.434
QTC								0.147	0.194	0.291	0.402
HEIGHT									0.796	-0.08	0.613
WEIGHT										0.368	0.57
BODYFAT											0.006

Table 6. Comparison of the Correlation values of different parameters of trained female table tennis players. (n= sample size, p=probability of error due to random sampling, NS = not significant, *=p<0.05, **=p<0.01).

	SYS	DIAS	HR	P	PR	QT	QTC	HEIGHT	WEIGHT	BODYFAT	RPP
AGE	0.147	0.221	0.258	0.213	-0.361	-0.204	0.218	0.298	0.345	0.326	0.310
SYS		**0.833****	-0.085	0.495	0.52	0.018	-0.072	**.757****	**.814****	**.727****	**.559***
DIAS			-0.167	0.472	**.564***	0.18	-0.074	**.675****	**.906****	**.763****	0.396
HR				-0.102	-0.259	**-.822****	**.786****	-0.393	-0.143	-0.294	**.770****
P					0.182	0.371	0.272	0.516	**.584***	0.523	0.299
PR						0.296	-0.05	0.497	0.441	0.508	0.117
QT							-0.303	0.431	0.204	0.351	**-.626***
QTC								-0.124	0.019	-0.042	**.647***
HEIGHT									**.748****	**.894****	0.161
WEIGHT										**.905****	0.419
BODYFAT											0.242

The correlation of one parameter with another was done to understand whether alteration of one parameter can influences the other to alter. In case of male swimmers Rate Pressure Product (RPP) is significantly correlated with Heart rate, QT interval and QTc where as male table tennis player shows significant correlation of RPP with Systolic Blood Pressure, Diastolic Blood Pressure, Heart Rate, PR and QTc. On the other hand in case of female table tennis players RPP are significantly correlated with Systolic Blood Pressure, Heart Rate, QT Interval and QTc but it is only significantly correlated with Heart Rate in female swimmers.

5 DISCUSSION

The objective of this study was focused on the myocardial oxygen demand and electrical activities of the heart between trained players of different sports and to find out the differences between swimmers male with table tennis players male and swimmers female with table tennis players female. Sub-elite trained endurance athletes are a unique group of individuals with increased left ventricular volume and resting heart rates generally less than 60 beats/minute. Electrocardiographic normal standards, especially these for QTc interval do not exist for these trained individuals [8]. The mean and standard deviation of Age (years), Stature (cm), Weight (kg), Total Body Fat Percentage (%),Systolic Blood Pressure (mm Hg), Diastolic Blood Pressure (mm Hg), Rate pressure Product, P (ms), PR (ms), QT (ms), QTc (ms) of both cases are not significant but the Heart Rate (beats/min) showed significant difference for both cases (male swimmers = 68.3±15.30, male table tennis players = 80.07±13.15, female swimmers = 77.00±9.01, female table tennis players = 91.64±14.07). Heart Rate is one of the most important parameter in sports science and it is varied due to cardiovascular events occur due to training adaptations [16]. QT Interval (ms) shows significant difference only in case of female group (swimmers = 374.67±20.62, table tennis players = 351.43±15.95) and it is higher in case of swimmers but only table tennis players are present in normal range (367-446 ms). The QT interval (ms) was the total ventricular systolic time measured from the onset of Q wave to the end of T wave. QT Interval represents the total time taken for ventricular depolarization and ventricular re-polarization. So it can measure the ventricular total systolic time which is found to be lower in case of female table tennis players but other three groups of players are present in normal range i.e. male swimmers (387 ms) and male table tennis players (367 ms). A prolonged QT time was one of the most important electrocardiographic abnormalities & an important cause of sudden cardiac death [17]. Trained endurance players have generally high left ventricular muscle mass and higher QTc (ms) values than untrained individuals [8]. In this study all QTc values are present in normal range (< 460 ms) So it may not mean that the heart is prone to arrhythmia. Rate Pressure Product is a valuable marker of the oxygen requirement in the heart in a given condition. 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. Rate Pressure Product (RPP) = Heart Rate (HR) X Systolic Blood Pressure (SBP) with the units for the Heart Rate being beats per minute and for the Blood Pressure mm Hg. Rate pressure product is a measure of the stress put on the cardiac muscle based on the number of times it needs to beat per minute (HR) and the arterial blood pressure that it is pumping against (SBP). It will be a direct indication of the energy demand of the heart and thus a good measure of the energy consumption of the heart. Rate pressure product allows us to calculate the internal workload or hemodynamic response. The Mean ± SD scores of RPP in case of both groups are not significant. RPP is calculated with the help of Resting Heart Rate so under resting condition safer RPP should range 7.00 (7000) – 9.00 (9000). 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 of heart disease [21,7] and low RPP values suggest the restricted coronary blood supply with inadequate ventricular function. Determining of cardiac oxygen consumption becomes important while training an athlete or in monitoring the level of exercise e to be done by others like cardiac and diabetic patients as well as normal person who are health conscious [13]. Whoever it may be, exercise should be in limit. Otherwise, it will have an adverse effect on body. In fact, if the cardiac muscle is overworked beyond 'limit', it may lead to development of angina. This limit can be determined by calculating RPP. RPP of 12.00 or below 12.00 with the Heart Rate of 60 – 120 beats/min and Systolic Blood Pressure of 100 – 140 mm Hg is considered to be normal without any existing or future risk of cardiovascular complications [24]. P (ms) represents the time taken to spread the impulse throughout the atria and therefore, the reason of P wave was the passage of the action current over the atria. No significant difference was observed between both cases. Atrial depolarization was lowest in case of both male (98.90 ms) and female (96.33 ms) swimmers than male (100 ms) and female (101.14 ms) table tennis players. And both cases males are higher than female. It might be due to higher atrial musculature in male and can only be confirmed by electrocardiography. PR Interval is the interval between the starting of P waves to the starting of QRS complex. The value of PR Interval (ms) is considered to be normal within the range (116-206 ms in male and 116-243 in female) in case of four groups. So there is no longer block in AV node or common bundle of His (due to long PR interval) and Wolf-Perkinson syndrome (due to short PR interval).

The correlation of one parameter to other is done to know how one parameter can influences other to change. RPP is positively and significantly correlated with Heart Rate ($p<0.01$) in case of both male and female trained swimmers but negatively correlated with QT ($p<0.01$) in case of only male swimmers. QTc ($p<0.01$) shows positive significant correlation only for male swimmers. On the other hand Systolic Blood Pressure ($p<0.01$), Diastolic Blood Pressure ($p<0.05$), Heart Rate ($p<0.01$) and PR Interval ($p<0.05$) shows positive significant correlation with RPP in case of male table tennis players, where as RPP shows positive significant correlation with Systolic Blood Pressure ($p<0.05$), Heart Rate ($p<0.01$) and QTc ($p<0.05$) but negative significant correlation with QT Interval ($p<0.05$) in case of female table tennis players. So it can be observed that when Rate Pressure Product will be changed Heart Rate and QT Interval can be changed in case of both trained players. All the cases show positive significant correlation with Heart Rate that means when RPP will be increased Heart Rate will also be increased. But QT Interval is inversely related with RPP because it shows negative significant correlation.

6 CONCLUSION

Regular intensive exercise training can change the structural and functional changes in the heart. Myocardial oxygen demand increases in exercise- induced heart after endurance training. In our findings, we can see that ventricular depolarization and repolarization time i.e. QT Interval is inversely related with Myocardial oxygen demand i.e. RPP. This phenomenon say that longer the ventricular event less will be the myocardial stress. During ventricular systole or depolarization heart contracts more forcefully and requires energy and oxygen is the source of this energy but during ventricular diastole or repolarization time heart relaxes this means heart is not in stressed condition and for this reason myocardial oxygen demand will be less. So, it might be concluded that more will be the ventricular repolarization or longer the ventricular diastolic time less will be the myocardial stress or oxygen demand. RPP is not only 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 RPP.

ACKNOWLEDGEMENTS

We thank the club authorities, coaches, guardians of the swimmers and table tennis players and no one but the players for their cooperation. We also express our thanks to the institutional ethical committee and the Department of Physiology, Serampore College for their consecutive support in this study.

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