Volume 08, Issue 02 (March-April 2025), PP 17-23 **www.ijmsdr.org**
ISSN: 2581-902X

International Journal of Medical Science and Dental Research

The Study of Changes in the QRS Complex between Resting Versus Peak Exercise in Children and Adolescent aged 10-15 Years

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ABSTRACT

Background: QRS complex can describe electrical conducting and related with ventricular function. Treadmill exercise stress test (tEST) was the importance tester for diagnosis most common coronary artery disease in adult, this method was monitor and record vital signs during exercise by Cardio-thoracic Technologist or health care specialist. The specificity and incooperation in children was limitation and give to reason for a few study about TEST and QRS complex in this age.

Materials and Methods: This retrospective study research aim to compared Q, R, S amplitude and QRS duration at rest versus peak exercise by treadmill in 10-15 years old. In the result, All 35 children (M=16, F=19)

Results Subject who underwent tEST(Modified Bruce protocol) were achieved target heart rate at peak exercise (stage 6 for averaged). In leads V_4, V_5, V_6, II and aVF we occurred Q and S amplitude were statistical significant more increased than resting phase about 0.5 and 1.4 boxes. In the opposite, R amplitude more decreased about 1 box (box=0.1 mV.) The QRS duration was slightly to decrease but not occurred statistic significant different.

Conclusions: At peak exercise period, Q and S amplitude was more increased and the R amplitude more decreased than resting period. But in the QRS duration not significantly different.

Keywords: Pediatric and adolescent, Electrocardiogram, QRS complex, Exercise stress test

I. INTRODUCTION

In the group of normal people, while exercising, the body changes and balance is systematically adjusted. There are also physiological and chemical mechanisms that stimulate the heart to contract faster and stronger in order to send enough blood to the extremities consistent with the activity being done. If a device is attached to measure vital signs while exercising, the device will clearly show the heart rate, blood pressure, and electrocardiogram. In particular, a treadmill Exercise Stress test administered by a Cardiothoracic technologist or other health professional will clearly show the heart's response on a monitor For example, electrical conduction of the atria is observed by the P wave, electrical conduction of the ventricle is observed by the QRS and T waves. From research that has been done on adults, it has been found that while exercising, the P and T wave graphs will increase in height (Amplitude) and will gradually increase. Decreases when entering the resting state.[1-2]The responses in males and females while exercising are similar.[3]But for the QRS wave or

QRS complex, it is considered very interesting because it can reflect the electrical current path related to the work of the ventricles and consists of 3 components: Q, R, and S wave (Figure 1).But most research like this tends to be done on samples of adults and tends to focus on coronary heart disease. Part of this may be because children are at an age where they do not cooperate. Or coronary heart disease is not a common disease in childhood, so there is still no indication for testing. Most studies that have been conducted in children have studied responses in asthma.[4]The information thus obtained is not from normal children, causing limitations in its use as a reference. And it was found that the study of Asian children or Thai children aged 10-15 years still did not have as much diverse information as was found. There was the only information studied in the old era. Nowadays, people's lifestyles may be different from before. Particularly with respect to ECG changes from the Modified Bruce protocol treadmill test, few studies have been conducted. Therefore, the question arose as to whether or not normal 10-15 year old children during maximum exercise would experience changes to the QRS complex, leading to this research study. This research aims to compare ECG's Q, R, and S amplitudes as well as QRS duration during resting and during maximal exercise.

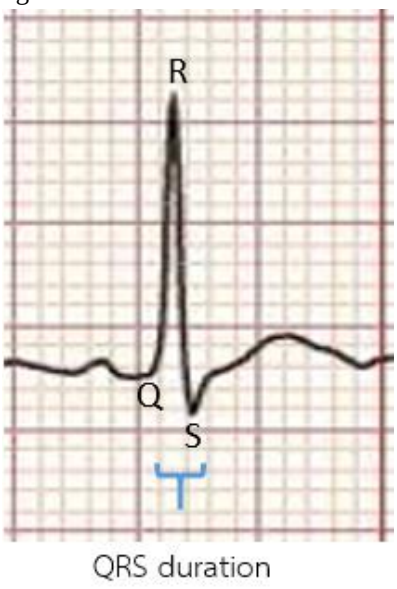

Figure 1 shows the ECG with QRS wave and QRS duration.
From: Ramathibodi Hospital

II. MATERIALS AND METHODS

This is there trospective research (Retrospective study) In the Population was sampling in aged 10-15 years group with test results Echocardiogram normal who received a heart fitness test by running on a treadmill in the Department of Pediatrics, which showed a clear ECG that could be measured. Inclusion criteria consist of
1) Have normal echocardiogram results.
2) Undergo tEST testing from Jan. 2017 – Dec. 2022. In the exclusion criteria consist of
1) Have echocardiogram results. Abnormal conditions, especially conditions that affect the QRS complex, such as cardiomyopathy, pericardial effusion, and various cardiac shunt conditions that affect the size of the heart chambers, etc. 2) The treadmill EST test results are negative. or unable to clearly measure the number of channels 3) Who had another congenital disease.

Review old treadmill exercise stress test; tEST results from 2017-2022, classifying the gender and age of the research participants. And count the number of channels of Q, R, S amplitude and QRS duration on the ECG test results at rest and during maximum exercise in leads II (Bipolar limb leads), and AVF (Unipolar limb leads), And V4, V5, V6 (Chest leads). This is because the QRS in leads V1-V3 will have an S dominant characteristic which is a Negative wave (inverted) as well as Leads I, aVR, AVL where the R wave characteristic will be Biphasic and/or Negative wave. In addition, during a very fast heartbeat, in addition to the movement of the chest wall which affects the isoelectric line characteristics, the T wave may overlap with the P wave of the next beat, which may cause confusion in classification and measurement (Figure 3).This research

therefore mainly focuses on QRS studies and does not use leads that are likely to cause errors to be processed like the Wolthuis RA study that studied only leads.[5]Subjects receiving treadmill test had their ECG recorded with electrodes placed at 6 points at the standard chest leads and 4 points at the modified limb leads (Hips and Shoulder under clavicle).All test results studied were from the GE brand T2100 machine using the Modified Bruce protocol of tEST (MODBRUCE). The machine records the ECG on paper and the belt increases every 3 minutes, with the first 9 minutes (3 stages) using a speed of 2.7, then increasing to 4, 5.4, 6.7 and 8 kilometers per hour every 3 minutes, respectively. This research was approved by the Human Research Ethics Committee. Faculty of Medicine Ramathibodi Hospital Mahidol University, number MURA 2025/64

Statistical analysis

We presented the patient information by descriptive statistics, Number (percentage) and Mean ± SD. We compared the number of channels of Q, R, S amplitude and duration between resting and maximal exercise by Wilcoxon Signed Rank test. Significant differences were accepted at *P*-value < 0.05.

III. RESULTS

A sample group of Thai children aged 10-15 years totaled 35 cases, 16 males (46%), 19 females (54%), 11 (31%) less than 13 years old, 24 (69%) aged 13 years and over. Most of them could run on a treadmill for a maximum of 18 minutes or stage 6 (maximum 24 minutes).None of the subjects were injured or had an accident while running that caused them to stop testing before reaching Target.[6]The most common reason for stopping running is due to exhaustion or exhaustion to the peak at unable to continue running. (Fatigue)

Table 1 The population characteristics

Data	Number (percentage) or Mean ± SD
Age< 13 years	11 (31%)
Age13 yearsabove	24 (69%)
GenderMale	16 (46%)
GenderFemale	19 (54%)
EchocardiogramLVEF(%)	66.1±5.08
MedianE/E'	8.5± 0.92
LVIDd(cm.)	4.7± 0.46
LV mass index(g/m^2)	98.2± 8.25

Note : Left ventricular ejection fraction; LVEF, Left ventricular internal dimension in diastole; LVIDd, Centimeter; cm., Left ventricular mass index; LV mass index, gram per $meter^2$; g/m^2

Table 2 The comparison of resting and maximal exercise heart rates.

Heart rate	Rest	Peak exercise	*P*-value
HR (bpm)	97 ± 12.5	181± 16.1	<0.05

Note; Heart rate; HR, beat per minute; bpm

Table 3 The number of QRS amplitude channels at rest versus peak exercise

Leads	ECG wave	Number of Voltage or Amplitude channels			*P*-value
		Rest	Peak exercise	difference	
V4	Q	1.22±1.27	1.87 ± 1.73	0.65	<0.05
	R	15.71±7.18	14.28±6.78	-1.43	<0.05
	S	5.04±3.28	7.28 ± 5.30	2.24	<0.05
V5	Q	1.44±1.76	1.88±1.88	0.44	<0.05
	R	15.08±5.44	14.37 ±6.00	-0.71	<0.05
	S	3.00±2.52	4.57±4.86	1.57	<0.05
V6	Q	1.34±1.44	1.80±1.58	0.46	<0.05
	R	12.50±3.95	11.55±4.42	-0.95	<0.05

	S	1.79±1.31	3.13±4.23	1.34	<0.05
II	Q	1.26±0.59	1.75±0.71	0.49	<0.05
	R	15.34 ± 6.57	14.68 ± 5.89	-0.66	<0.05
	S	2.52 ± 2.40	3.34 ± 2.02	0.82	<0.05
aVF	Q	1.18 ± 0.54	1.74 ± 0.77	0.56	<0.05
	R	14.80 ± 6.20	13.77 ± 5.33	-1.03	<0.05
	S	1.85 ± 1.49	2.85 ± 2.03	1	<0.05

Note: onesmall box= 0.1 millivolt (mV), - = Decrease

Table 4 The number of channels of QRS duration at rest versus peak exercise.

Leads	ECG wave	Number of duration channels			*P*-value
		Rest	Peak exercise	difference	
V4	Q	0.95 ± 0.18	0.98 ± 0.08	0.03	0.317
	R	1.07 ± 0.27	0.98 ± 0.08	-0.09	0.063
	S	1.01 ± 0.08	1.01 ± 0.08	0	1.000
V5	Q	1.02 ± 0.16	1.01 ± 0.14	-0.01	0.705
	R	1.05 ± 0.20	1.00 ± 0.01	-0.05	0.102
	S	0.97 ± 0.11	1.01 ± 0.08	0.04	0.083
V6	Q	0.95 ± 0.14	0.98 ± 0.08	0.03	0.157
	R	1.00 ± 0.01	1.00 ± 0.01	0	0.100
	S	0.97 ± 0.11	1.00 ± 0.17	0.03	0.317
II	Q	1.01 ± 0.25	1.04 ± 0.14	0.03	0.603
	R	1.10 ± 0.23	1.04 ± 0.14	-0.06	0.102
	S	0.90 ± 0.20	1.02 ± 0.11	0.12	<0.05
aVF	Q	0.98 ± 0.25	1.00 ± 0.12	0.02	0.527
	R	1.12 ± 0.25	1.07 ± 0.21	-0.05	0.279
	S	0.90 ± 0.20	1.04 ± 0.18	0.14	<0.05

Note: onesmall box= 0.1 millivolt (mV), - = Decrease

IV. DISCUSSIONS

In Thai children aged 10-15 years without heart disease, there were equal numbers of males and females.(Table 1) Echocardiogram results did not reveal cardiomyopathy. or lose face in squeezing and relaxing When exercising until you are extremely tired and your heart rate doubles.(Table 2) The QRS complex in leads V4 V5 V6 ll and aVF was found to be significantly different from that at rest (P-value <0.05), which is similar to the response in adults.[7]

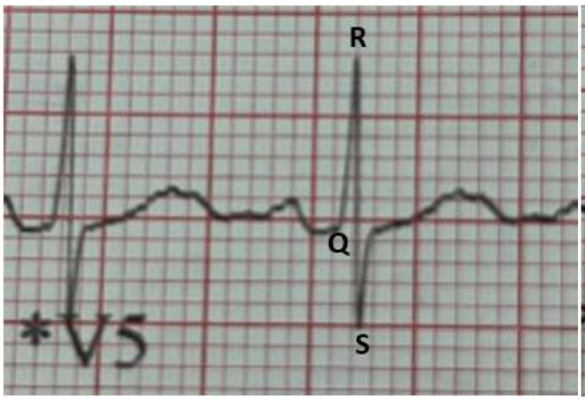

Figure 2 The QRS complex before exercise.

Figure 3 The QRS complex changing during exercise.

A normal R wave has the characteristics of a positive wave (upright) caused by the muscles in the Ventricular mostly compressing parallel to the electrical conduction direction, thus appearing upright. But the research found that when exercising, the height of the R graph or R amplitude decreases. The height of R

amplitude during maximum exercise was significantly lower than during rest (P-value <0.05), consistent with the study by Bonoris PE et al.who reviewed the tEST test results in a sample of 266 healthy adults found that the R amplitude of normal people should decrease while exercising.On the other hand, cases in which R amplitude remains the same or increases during heavy exercise mostly appear in those with abnormalities of the coronary artery system.[7]It is related to myocardial blood flow and other factors such as the size of the cavity in the heart or the increased blood volume in the heart while exercising will cause the electrical potential difference to decrease, resulting in a shorter R amplitude.Similar to conditions where there is increased water or air in the lungs, it will obscure or cause the electrode to be further away from the heart, so the R amplitude will be shorter. There is also an Electrical axis change factor involved as well.[8-9]

Q wave has negative wave characteristics (inverted). Some cases are very small, especially while resting. This is caused by Septal depolarization. Is the direction from left to right or opposite to the direction of cardiac electrical conduction, which runs from the right to the left. Therefore, when exercising, the heart will contract (Force) more forcefully, so the Q amplitude will increase or deepen because the movement and increased force of compression affect the electric potential as well.[9]Similar to the study by Furuse T and colleagues that found that in normal people who exercise, Q amplitude is deeper than during rest. But in patients with heart muscle and coronary artery system problems, Q amplitude remains constant or does not change at all.[10]

S wave has the same negative wave characteristics as Q and is caused by Ventricular depolarization. It spreads backward until it reaches the top of the ventricle, causing it to appear as a negative wave.From this research, it was found that while exercising to the maximum, S amplitude will be deeper than while resting, consistent with a study by Wolthuis RA and colleagues that studied adults since 1979, which found that S amplitude while exercising will be deeper and statistically significant until resting for a period of time before it will be close to normal again.The R amplitude and R interval were shorter and narrower from baseline, with the greatest decrease during the peak exercise period. But when entering the resting period (Recovery), these values will gradually increase. increased until it was equal to the baseline again.[5,6,11]

In terms of QRS duration, this study found no significant difference between resting and maximal exercise, similar to the study by Simoons M et al.[2]However, there are other studies that indicate that in normal people the QRS duration should be lower during exercise than during rest.[8,10]However, about half of the QRS duration values in this study were found to be lower during maximal exercise than during resting, but with only a slight difference, when statistical analysis was not found to be a significant difference. (Table 4) In addition, most studies use computers to measure and process the QRS duration, which should be more accurate than this research, which measured by hand, especially in the QRS wave, which in some cases is only half a channel narrow, which is difficult to compare.

From studies in another country, it is known that in normal children while exercising, P and T amplitude increases, PR duration decreases, and QT interval increases with statistical significance.[3,4,12]But for data on Thai children, further studies are still needed because there are limitations in the overlapping of P waves and T waves while exercising, which makes it difficult to measure and analyze results (Figure 3).However, the results of this study will help complement and confirm the data from studies on the QRS complex of children because it will not only reveal the different characteristics of QRS changes during rest and during exercise. But it also gives you an idea of things related to cardiac morphology.From research by Bunmee U that compared ECGs from sitting and lying positions in children aged 4-11 years, it was found that the sitting position causes the heart to be closer to the center of the body, which is farther from the chest wall or the electrode attached for recording the ECG, causing the R amplitude to be found to be approximately 3 channels lower than the average lying position, especially in the chest leads.[13]According to this research, even though jogging makes the heart beat faster and stronger or has more movement until the ripples of the chest wall can be observed or felt. But it was found that these conditions did not cause the QRS to increase even with maximum exercise.On the contrary, this R amplitude becomes shorter, which is in accordance with the principle of increased blood volume resulting in a decrease in Cavity in the heart, which is related to a decrease in electric potential difference, or similar to having more air in the lungs as a barrier.[14-15]However, interpreting and diagnosing LV hypertrophy with Resting 12 leads ECG still recommends testing in the supine position, which is the standard position under conditions where the patient has not received any stimulation of the sympathetic system,[16]such as running,

being excited, hurrying, crying, being afraid because even though these conditions do not cause an increase in LV voltage, they may cause the heart rate to be faster than normal.

Limitations of the study

This study did not study leads I III aVRaVL because such leads already have both biphasic wave and negative wave characteristics. Therefore, while exercising the isoelectric line moves a lot, making manual measurement difficult and having a higher chance of error than research studies that measured with a machine.In addition to being primarily interested in QRS change, a review of the literature found that when the heart beats very fast, the P and T waves overlap, which is difficult to classify or accurately measure. Therefore, we chose to study and measure only the clear parts.

V. CONCLUSIONS

In normal Thai children aged 10-15 years, when they exercised by running on a treadmill until they reached maximum fatigue, it was found that the QRS complex in leads V4 V5 V6 ll and aVF was significantly different from that at rest. (P-value < 0.05) The Q wave was 0.5 channels deeper, the R amplitude was 1 channel shorter, and the S wave was 1.4 channels deeper. It was found that while exercising to the maximum, the R duration tended to be lower than while resting, but for the most part, no statistically significant differences were found.

ACKHOWLEDEMWNTS

Thank you to Ramathibodi Library for providing information materials and a place to do research. Thank you to the Division of Cardiology, Department of Pediatrics Faculty of Medicine, Ramathibodi Hospital, which has given permission to use the data. We would like to thank the Society of Cardio-Thoracic Technologist (Thailand) for support equipment.

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