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Original Article

Evaluation of Electrocardiographic Markers for the Risk of Cardiac Arrhythmia in Children with Obesity

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ABSTRACT

Aim: This study was conducted to examine the electrocardiographic markers used in the risk assessment of cardiac arrhythmia in children with obesity.

Materials and Methods: In this prospective study, 60 children aged 3-17 years with exogenous obesity and 60 age and sex-matched healthy controls were included. Demographic data, assessment of atrial and ventricular arrhythmia risk markers in electrocardiography, and standard echocardiography measurements were performed. Values of $p<0.05$ were considered significant.

Results: The mean ages of the study and control groups were 11.51±3.48 years and 10.74±3.72 years, respectively. Both groups had 30 males and 30 females. The study group had significantly higher average mean body mass index (BMI) compared to the control group. In electrocardiographic examinations, P-wave dispersion, QT dispersion (QTd), corrected QTd (QTcd), Tpeak-Tend (Tp-e), Tp-e/QT, and Tp-e/QTc values were significantly higher in the obese group compared to the control group. In echocardiographic examinations, the dimensions of the heart chambers and vascular structure and wall thicknesses were found to be significantly higher in those children with obesity.

Conclusion: The electrocardiographic risk markers used to predict cardiac arrhythmias were found to be increased in those children with obesity. This may suggest that increased body weight and adiposity may have unfavorable effects on the cardiac conduction system.

Keywords: Child, electrocardiography, heart, obesity

Introduction

Childhood obesity, defined by the World Health Organization (WHO) as “abnormal or excessive fat accumulation in the body to the extent that it impairs health”, is a global disease with potentially devastating consequences (1). Obesity-related cardiovascular diseases (coronary heart disease, cardiomyopathy, heart failure, cardiac arrhythmias, and heart valve diseases) and impairments (left ventricular hypertrophy, left ventricular dilatation, left atrial dilatation, and blocks) may develop (2). Obesity also paves the way for disruption in the myocardial metabolism and arrhythmia in the heart with changes in fat metabolism. Sinus arrhythmia, bradycardia, sinus

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block, supraventricular beats, ventricular ectopic beats, and intraventricular blocks can be seen in obesity (3).

P-wave dispersion (Pd) is defined as the difference between the longest and shortest P-wave intervals measured in a standard 12-lead electrocardiogram (ECG) (4). It is associated with the inhomogeneous spread of sinus impulses in patients and it is an important non-invasive ECG marker recommended in the evaluation of the risk of atrial arrhythmia (5). QT dispersion (QTd) is a parameter which shows ventricular repolarization heterogeneity (6). It has been shown that QT, corrected QT (QTc), and QTd predict ventricular arrhythmic events and sudden death (7). The Tpeak-Tend interval (Tp-e), an interval from the peak of the T-wave to the end of the T-wave, corresponds to the transmural distribution of ventricular repolarization (8). Tp-e is a new parameter which shows ventricular repolarization and predicts ventricular arrhythmias and sudden death even in those with normal QTc. Both Tp-e and Tp-e/QT ratios have been associated with malignant arrhythmias (9). This study was conducted in order to evaluate cardiac arrhythmia risk markers on the ECGs of children with obesity.

Materials and Methods

Study Group

Our study was conducted prospectively, cross-sectionally, and observationally in children aged 3-17 years between June, 2020 and December, 2020. Sixty children who were followed up with a diagnosis of exogenous obesity were included in the patient group. The exclusion criteria were defined as having a chronic disease other than exogenous obesity and having congenital or acquired heart disease. Sixty healthy children without chronic diseases, who were matched with the study group in terms of age and sex, were included in the control group. Ethical approval was obtained for our study from the Necmettin Erbakan University Meram Faculty of Medicine, Non-Pharmaceutical and Medical Device Research Ethics Committee (decision number: 2020/2605, dated: 19.06.2020).

Clinical and Laboratory Evaluations

Anthropometric measurements [body weight, height, and body mass index (BMI)], age, sex, blood pressure, and physical examinations were evaluated in the study and control groups. Complete blood count, biochemistry, and hormonal tests, which were taken routinely in the patient group, were evaluated. No blood tests were performed in the control group.

Electrocardiographic Evaluations

Electrocardiographic records were obtained using a 12-lead Nihon Kohden Cardiofax S (Tokyo, Japan) electrocardiograph (25 mm/sec velocity and 10 mm/mV amplitude). The ECG images were transferred to a computer in a way that their planarity would not be impaired. The images were evaluated by an experienced physician using a program. Heart rate and PR interval calculations were performed by averaging three consecutive measurements from the DII lead. P-wave duration measurements were made from at least nine leads. The time between the starting and ending points of the P-wave from the isoelectric line was evaluated as the P-wave interval, and then the longest (Pmax) and the shortest (Pmin) P-wave intervals were also determined. Pd was evaluated as the difference between the longest (Pmax) and shortest (Pmin) P-wave intervals (4). QT duration measurements were also made from at least nine leads. The time between the onset of the QRS complex and the junction of the T wave with the isoelectric line was measured as the QT interval. QTd was calculated as the difference between the longest (QTmax) and shortest (QTmin) QT intervals. QTc was calculated according to heart rate using Bazett's formula ($QTc=QT/\sqrt{RR}$) (10). QTc dispersion (QTcd) was determined as the difference between the longest (QTcmax) and the shortest (QTcmin) QTc intervals.

The Tp-e interval was determined by measuring the time between the peak of the T wave and the junction with the isoelectric line. The precordial lead (V5 or V6) which best showed the left ventricle was used when measuring. The tangent method was used when the cut-off point of the end of the T-wave with the isoelectric line could not be evaluated. Tp-e/QT and Tp-e/QTc ratios were calculated by measuring QT and QTc from the same lead (precordial lead) where the Tp-e time was measured.

Echocardiographic Evaluations

The Vivid S5 N (GE, Horten, Norway) echocardiograph and 3S probe were used for echocardiography (ECHO) examinations. A standard examination was performed by an experienced pediatric cardiologist with the techniques specified in the guidelines of the American and European Society of Echocardiography, which are accepted in international practice (11,12). During the ECHO examination of the patients, left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), left atrium (LA), aortic root (Ao), end-diastolic interventricular septum thickness (IVSd), end-diastolic left ventricular posterior wall thickness (LVPWd), ejection fraction (EF), and fractional shortening (FS) measurements were made.

Statistical Analysis

The IBM SPSS for Windows® 22.0 program was used for the statistical analysis of the data. Frequencies, ratios, mean and standard deviations of different variables were determined using descriptive statistics. The Kolmogorov-Smirnov test was used to evaluate the conformity of continuous data to the normal distribution. Continuous data which did not show normal distribution were tested for their conformity to the normal distribution through data transformation. In the analysis of normally distributed continuous variables, the t-test was used in independent paired groups to determine differences between the groups, and the Mann-Whitney U test was used in the analysis of independent paired groups of continuous variables which did not show normal distribution. A p-value of <0.05 was considered statistically significant in the analyses.

Results

Characteristics of the Groups

The mean age of the study group and control group was 11.51±3.48 years and 10.74±3.72 years, respectively. The male/female ratio was 30/30 in both groups. There was no significant difference between the study and control groups in terms of age and sex (p>0.05). However, body weight (p<0.001), height (p=0.001), BMI (p<0.001), and BMI-standard deviation scores (SDS) (p<0.001) were found to be significantly higher in the study group compared to the control group. In addition, systolic and diastolic blood pressures were found to be significantly higher in the study group compared to the control group (p<0.001). The general characteristics of the groups are summarized in Table I.

Laboratory Findings

Laboratory findings were obtained from the files of the study group. No blood was collected from the control group. Therefore, a comparison between the two groups could not be made. The blood values of the study group are shown in Table II together with the laboratory reference values.

Table I. Comparison of the general characteristics of the patient and control groups

	Obese subjects (n=60)	Lean subjects (n=60)	p-value
	Mean ± SD	Mean ± SD	
Age (years)	11.51±3.48	10.74±3.72	0.246
Gender (female/male)	30/30	30/30	0.999
Weight (kg)	74.30±25.73	37.00±15.31	<0.001
Height (cm)	151.78±19.66	139.57±18.87	0.001
Body mass index (kg/m²)	31.09±4.83	18.06±3.44	<0.001
Body mass index-SDS	2.42±0.37	0.00±1.07	<0.001
Systolic blood pressure (mmHg)	119.25±12.06	102.42±10.95	<0.001
Diastolic blood pressure (mmHg)	76.72±8.57	66.00±9.37	<0.001

SD: Standard deviation, SDS: Standard deviation scores

Table II. Laboratory values of the patient group

Laboratory values	Mean	SD	Median	Highest	Lowest	Higher compared with reference (%)	Reference values
Glucose (mg/dL)	91.52	7.35	91.35	109.80	71.00	8.3	60-100
Insulin (mU/L)	26.42	11.90	24.80	59.26	7.78	49.1	2.6-24.9
HbA1C (%)	5.17	0.32	5.20	6.00	4.40	1.7	4-6
Cholesterol (mg/dL)	160.08	33.80	159.45	242.70	90.90	10.3	0-200
Triglyceride (mg/dL)	157.80	110.26	136.70	722.30	48.80	42.3	0-150
VLDL (mg/dL)	30.09	19.86	26.90	140.20	9.76	39.2	0-30
HDL (mg/dL)	43.88	9.15	44.70	61.50	16.70	67.2	0-40

Table II. Continued

Laboratory values	Mean	SD	Median	Highest	Lowest	Higher compared with reference	Reference values
LDL (mg/dL)	85.23	28.64	86.36	160.46	10.77	26.7%	0-100
AST (U/L)	26.83	14.30	22.90	93.00	10.50	8.3%	0-41
ALT (U/L)	33.03	26.89	23.20	174.30	10.00	21.6%	0-40

ALT: Alanine aminotransferase, AST: Aspartate aminotransferase, HbA1c: Hemoglobin A1c, HDL: High-density lipoprotein, LDL: Low-density lipoprotein, VLDL: Very low-density lipoprotein, SD: Standard deviation

Electrocardiographic Parameters

The Pd, QTd, QTcd, Tp-e durations, and Tp-e/QT and Tp-e/QTc ratios were found to be significantly higher in the study group compared to the control group (p<0.001). Heart rate and PR interval time were found to be similar between the groups (p>0.05). No patients had arrhythmia or a long QTc interval. The electrocardiographic measurement findings and statistical comparisons are given in Table III.

Echocardiographic Parameters

The dimensions of the cardiac chambers and vessels (LVESD, LVEDD, Ao, LA) and the wall thicknesses (IVSd, LVPWd) of the study group were found to be significantly greater (p<0.001). However, there was no significant difference between the groups in terms of the LA/Ao ratio or systolic functions (EF and FS) (p>0.05) (Table IV).

Table III. Electrocardiographic features of the obese and control groups

	Obese subjects (n=60)	Lean subjects (n=60)	p-value
Rate (/min)	94.5±18.63	89.63±16.06	0.128
PR (ms)	123.43±15.87	121.8±13.62	0.546
Pmin (ms)	56±7.9	56.67±6.8	0.621
Pmax (ms)	89.33±7.75	81.07±6.54	<0.001
Pd (ms)	33.33±4.27	24.4±3.01	<0.001
Qtmin (ms)	291.27±26.92	297.13±25.44	0.222
Qtmax (ms)	329.67±26.6	323.2±25.49	0.177
QTd (ms)	38.4±5.9	26.07±3.86	<0.001
Qtcmin (ms)	361.09±22.71	359.67±23.35	0.736
Qtcmax (ms)	408.94±22.76	391.36±24.41	<0.001
QTcd (ms)	47.85±8.04	31.69±5.41	<0.001
Tp-e (ms)	65.57±5.08	58.07±4.2	<0.001
Tp-e/QT	0.21±0.02	0.19±0.02	<0.001
Tp-e/QTc	0.17±0.01	0.15±0.02	<0.001

Pd: P dispersion, Pmax: Maximum P-wave duration, Pmin: Minimum P-wave duration, QTcd: QTc dispersion, QTd: QT dispersion, QTcmax: Maximum QTc duration, QTcmin: Minimum QTc duration, QTmax: Maximum QT duration, QTmin: Minimum QT duration

Table IV. Echocardiographic features of the obese and control groups

	Obese subjects (n=60)	Lean subjects (n=60)	p-value
LVEDD (mm)	44.26±5.04	39.4±4.87	<0.001
LVESD (mm)	26.59±3.51	23.39±3.25	<0.001
IVSd (mm)	8.12±1.33	7.12±1.67	<0.001
LVPWd (mm)	8.5±1.37	7.13±1.07	<0.001
LA (mm)	30.5±5.39	26.18±3.74	<0.001

Table IV. Continued

	Obese subjects (n=60)	Lean subjects (n=60)	p-value
AO (mm)	24.03±3.85	22.00±2.85	<0.001
LA/AO	1.27±0.14	1.25±1.15	0.542
EF (%)	69.42±8.71	71.27±3.42	0.128
FS (%)	39.92±3.02	39.47±5.73	0.837

AO: Aortic root, EF: Ejection fraction, FS: Fractional shortening, IVSd: End-diastolic interventricular septum thickness, LA: Left atrium diameter, LA/AO: Left atrium diameter to aortic root ratio, LVEDD: Left ventricular end-diastolic diameter, LVESD: Left ventricular end-systolic diameter, LVPWd: End-diastolic left ventricular posterior wall thickness

Discussion

The prevalence of obesity is increasing worldwide and it constitutes an important economic and public health problem due to its morbidity and mortality (13). The fact that obesity is observed in childhood means that cardiovascular diseases will begin at a younger age, the burden of chronic disease will begin to appear in the most productive years of people, and it will worsen public health (14). In previous studies, it was shown that obesity increases the risk of atrial fibrillation (AF), the risk of AF increases again in adults who were obese in childhood, and it was shown that losing body weight reduces the risk of AF (15,16).

The prevalence of childhood hypertension in children with obesity increases as blood pressure shifts towards higher levels as body weight increases (17). A close relationship has been shown between BMI and blood pressure levels in overweight adolescents. In one study, it was found that every 10-unit increase in BMI was associated with an increase of 10 mmHg in systolic blood pressure and 3 mmHg in diastolic blood pressure (18). Body weight, BMI, and BMI-SDS values were higher in our obese group in comparison to the control group, which were similar in terms of age and sex. Similar to previous studies, both systolic and diastolic blood pressures were found to be significantly higher in the obese group in our study.

Pd is associated with the inhomogeneous spread of sinus impulses in patients and it is an important ECG marker in the evaluation of the risk of atrial arrhythmia (5). Although a significant increase in Pd was observed in studies conducted in adult patients with obesity, there have been conflicting results in studies conducted in children. In the study of Akyüz et al. (19) performed with 67 children with obesity and 70 controls, no significant difference was found between the two groups in terms of Pd. Another pediatric age group study was conducted with 30 children with obesity and 30 controls, and Pd in the obese group was found to be significantly higher than in the control group (51.33±11.67 ms vs. 39.67±11.59 ms, $p<0.05$) (20). In another study performed with 59 children with obesity and 38 healthy volunteers, Pd was found to be significantly higher in the patient group (21). In our study, Pd was found to be significantly higher in obese children. Accordingly, as Pd is an indicator of susceptibility to atrial arrhythmia, children with obesity should be followed up losely. Also, the importance of losing body weight should be emphasized to families and children in order to reduce risk.

It has been shown that QT, QTc, and QTd predict ventricular arrhythmic events and sudden death (7). Studies have been conducted on QT, QTc, QTd, and QTcd in children with obesity and these values increased with obesity. In a study conducted with 81 children with obesity and 82 normal-weight children in our country, a significant increase was found in QTd and QTcd (22). Olivares López et al. (23) found the mean QTc values to be significantly longer in the obese group in a limited study conducted with 13 patients with obesity and 17 overweight individuals. In another study, it was shown that QTcd was found to be significantly higher in the obese group (24). In the study conducted by Ozkan et al. (25) with 45 children with obesity and 87 normal-weight children, they found the mean QTc values to be significantly higher in the obese group.

Tp-e interval is a relatively new ECG parameter which shows ventricular repolarization and predicts ventricular arrhythmias and sudden death, even in those with normal QTc. Both the Tp-e interval and Tp-e/QT ratio have been associated with malignant arrhythmias (9). There are insufficient data in the literature on these parameters because they have only just begun to be studied, even in adults with obesity. In one study conducted with adult patients, it was shown that Tp-e interval and Tp-e/QT ratio values were higher in the obese group, but no significant difference was found between the groups (26). Another study in the adult age group was conducted with 41 individuals with extreme obesity and 41 healthy people, and they found that the Tp-e interval and ratios of Tp-e/QT and Tp-e/QTc were significantly increased in the patient group (7).

In another study conducted with 126 healthy children aged 9-12 years, the Tp-e/QT ratio and anthropometric values were compared, and a significant linear correlation was found between the Tp-e/QT ratio and BMI (27). Türe et al. (28) showed that in children with obesity, heart rate, PR interval, Pd, QRS duration, QTd, QTcd, left ventricular hypertrophy, and Tp-e interval were found to be statistically different from healthy controls. In our study, the Tp-e interval, and ratios of Tp-e/QT and Tp-e/QTc were found to be significantly higher in the obese group. The fact that transmural repolarization indicators (Tp-e interval, Tp-e/QT ratio, Tp-e/QTc ratio) were found to be higher in our patient group together with other ventricular repolarization parameters (QTd and QTcd) compared to the control group supported the increased risk of ventricular arrhythmia in children with obesity. To the best of our knowledge, there are a limited number of studies on the ECG parameters of children with obesity. Thus, our study may contribute to the literature.

In one study conducted on children, LVEDD was found to be significantly increased in the obese group compared to the control group (20). In our study, it was observed that LVEDD was significantly higher in the obese group compared to the control group, which is consistent with the literature. In many studies in the literature, IVSd and LVPWd were evaluated in children with obesity and it was observed that these parameters were higher in the obese groups. Studies conducted with various numbers of patients with obesity showed that IVSd and LVPWd were significantly higher in children with obesity (20,29,30). In our study, in accordance with the literature, IVSd and LVPWd were significantly higher in the obese group.

LA size is an important determinant of cardiovascular health in adults. In a study performed with 991 children, a relationship was found between BMI and LA size (31). In the study of Hurtado-Sierra (32) on 142 participants including 53 obese and 39 overweight volunteers, LA size was found to be significantly higher in the obese group. In our study, LA diameter was found to be significantly higher in the obese group compared with the control group. Üner et al. (20) and Ghandi et al. (30) both observed that there were no significant differences in terms of systolic functions between the obese and control groups. In our study, in line with the literature, it was observed that systolic functions were preserved in the obese group and also, they were similar to the control group. According to our echocardiographic findings, it was observed that the width of the heart/vessels and wall thicknesses were higher in childhood obesity. We think that this is due to increased body mass, fat proportion, and arterial blood pressure.

Study Limitations

The cardiac evaluations of our patients were cross-sectionally performed at the time of diagnosis. Our data were obtained in the early period of obesity; therefore, long-term cardiac changes in the patients could not be followed. For this reason, we think that comparing long-term and post-weight loss cardiac evaluations will yield more meaningful results.

Conclusion

It was observed that in addition to increased body weight, BMI, and BMI-SDS in children with obesity, heart/vessel widths, wall thicknesses, and blood pressure also increased. Electrocardiographic risk markers for the prediction of atrial (Pd) and ventricular (QTd, QTcd, Tp-e, Tp-e/QT, and Tp-e/QTc) cardiac arrhythmias were found to be higher in our children with obesity group. This suggests that increased body weight and adiposity may affect the electrical conduction system of the heart, and thus it is important to be vigilant in terms of heart rhythm problems which may develop in children with obesity. It is important to explain to patients and their relatives that losing body weight can reduce these risks. However, further studies are needed on this issue.

Ethics

Ethics Committee Approval: Ethical approval was obtained for our study from the Necmettin Erbakan University Meram Faculty of Medicine, Non-Pharmaceutical and Medical Device Research Ethics Committee (decision number: 2020/2605, dated: 19.06.2020).

Informed Consent: Informed consent was obtained from all individuals included in this study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: F.Ş., M.E.A., T.B., Design: H.Y.D., F.Ş., B.S.E., T.B., Data Collections or Processing: H.Y.D., F.Ş. M.E.A. T.B., Analysis or Interpretation: F.Ş., M.B.O., B.S.E., T.B., Literature Search: H.Y.D., F.Ş., M.B.O, Writing: H.Y.D., F.Ş.

Conflict of Interest: None of authors have any conflicts of interest to report.

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