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Original Article

Electrocardiogram abnormalities in obese adolescents

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Abstract

Background Obesity in adolescents is a known risk factor for cardiovascular disease mortality and sudden cardiac death. Obesity is associated with a wide variety of electrocardiogram (ECG) abnormalities.

Objective To assess prevalence and describe the ECG abnormalities in obese adolescents.

Methods This cross-sectional study was conducted at Children's Cardiology Clinic - Integrated Heart Center of Sanglah General Hospital, Denpasar, Bali, by recording ECGs of obese adolescents aged 11-15 years from several junior high schools from December 2016 to April 2017. The inclusion criteria were obese adolescents aged 11 to 15 years, who were willing to participate in the study and provided informed consent.

Results A total of 78 ECGs of obese adolescents (60% male) were selected. Subjects' mean weight and age were 82.6 (SD 15.2) kg and 13.2 (SD 1) years, respectively. Pre-hypertension was found in 25 (32%) subjects, while hypertension was found in 18 (23%) subjects. There were 29 (37%) subjects with abnormal ECGs. Sinus tachycardia was present in 13 (17%) subjects, and sinus arrhythmia was identified in 11 (14%) subjects. Eight (10%) patients experienced prolongation of QTc interval and 5 (6%) patients presented with prolongation of PR interval. There were no shifts of the P wave, QRS wave and T wave axes, changes of P wave morphology, low QRS voltage, T wave flattening, ventricular enlargement, or ST segment changes found in this study.

Conclusion The prevalence of cardiac abnormalities based on ECG examination in obese adolescents is 37%, consisting of heart rhythm abnormalities, prolonged PR interval, and prolonged QTc interval. **[Paediatr Indones. 2020;60:18-23; doi: http://dx.doi.org/10.14238/pi60.1.2020.18-23]**.

Keywords: *electrocardiography; obese; adolescents*

Obesity in adolescents is a community health problem and a factor which increases morbidity and mortality in adolescents.[1] The prevalence of overweight and obesity in adolescents has increased three times during the last two decades in the US, and almost all were classifed as obese by the time they reached adulthood.[2] It is suspected that the increase in obesity prevalence in adolescents is caused by lack of physical activity, changes in lifestyle, and inappropriate nutritional intake. Obesity in adolescents is related to increased risk of type 2 diabetes, hypertension, stroke, metabolic syndrome, and cardiovascular disease.[3]

The National Health Examination Survey in the US estimated that approximately 17% of children and adolescents developed obesity. Another study indicated an increase of obesity prevalence in adolescents ranging from 12-19 years of age in the US from 5% in 1980 to 21% in 2012.[2,3] The 2013 National Basic Health Research (*Riset Kesehatan Dasar/RISKESDAS*) data showed that the prevalence of overweight and obesity in adolescents aged 13-15 years was 10.8%, consisting of 8.3% overweight and

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2.5% obese. *The 2013 RISKESDAS* data showed that the highest prevalence of obesity was in the 13-15-year age group nationally, while the prevalence of obese adolescents in Denpasar, Bali, was 15.2%.[4]

High obesity rates in adolescents also increases the risk of closely related diseases, one of which is cardiovascular disease. A study in 2002 showed that obese adolescents had three times higher risk of experiencing hypertension compared to non-obese adolescents.[5] Obesity can lead to changes in heart structure and function which can increase the risk of cardiovascular disorders in adults. Several studies found a close relationship between obesity and cardiovascular disorders including hypertension, arrhythmia, left atrial enlargement, and decreased systolic and diastolic function.[6,7]

The correlation between obesity and ECG abnormalities has been studied by several researchers. Obesity is considered closely related to an increase in resting heart rate, as well as elongation of the PR interval and duration of QRS.[6,8] Another study showed a correlation between obesity and elongation of the QT interval and leftwards displacement of the heart axis.[6] A study performed in Manado, North Sulawesi, showed an increase in left ventricular hypertrophy in children with obesity, but the result was not statistically significant.[9] A Vienna, Austria study showed that decreasing the weight of obese children and adolescents could change their electrocardiographic findings, decrease heart rate, and shorten QT interval.[10] A study in Lagos, Nigeria showed no statistically significant differences between obese adolescents and controls, but the study revealed that 9 of 49 (18.3%) obese adolescents presented with prolonged QTc.[11] Studies regarding obesity and ECG abnormalities were mostly performed in adults, and only a few was performed in adolescents and children. Data regarding electrocardiographic image in obese adolescents is still lacking, especially in Indonesia.

Electrocardiographic examination is easy, inexpensive, non-invasive, and readily available in all healthcare facilities in every city and district in Indonesia. This examination may be useful as the initial screening tool to detect heart abnormalities in obese adolescents, thus early detection and intervention can be achieved before heart structure changes become irreversible.[6,8]

Methods

This cross-sectional study was conducted at the Children's Cardiology Clinic - Integrated Heart Center of Sanglah General Hospital, Denpasar, Bali. Obese adolescents from several junior high schools in Denpasar underwent ECGs from December 2016 to April 2017.

Inclusion criteria were obese adolescents aged 11 to 15 years, who were willing to participate in the study and provided informed consent. The exclusion criteria were those with a history of chronic diseases, receiving drugs that were known to interfere with cardiac or respiratory function, or a history of chronic alcohol or tobacco consumption. The minimum sample size was determined to be 76 subjects, using a sample calculation formula for categorical descriptive data.

Obesity in adolescents was defined as body mass index (BMI) more than 2 standard deviations (SD) based on the 2007 WHO BMI-for-age curve.[11] Subjects were classified as obese if the BMI was within 2-3 SD, and severe obesity if the BMI was more than 3 SD. QTc interval prolongation is the prolongation of the QT interval after corrected heart rate, which can be evaluated through ECG examination. The interval value of QTc > 0.44 seconds was considered to be prolonged. Prolonged PR interval was the extension of the PR interval. If the value of the PR interval exceeded the limit according to age and heart rate, it was considered to be prolonged.

All subjects underwent a thorough cardiac evaluation including past medical history, physical examination, anthropometric evaluation, and 12-lead ECG examination. The same 12-lead ECG (*Fukuda Denshi*®) was used for all subjects. A paper speed of 25 mm/s and an amplitude of 10 mm/mV were used. The ECGs were recorded and analyzed by the same physicians throughout the study and confirmed by a pediatric cardiologist.

Data obtained were analyzed with *SPSS ver. 20.0* software using descriptive analysis for subjects' characteristics and variables studied. Sample characteristics included in categorical variables were shown as number (n) and percentage (%), while numerical variables were shown as mean (SD). This study was approved by the Research Ethics Committee at Universitas Udayana Medical School, Sanglah Hospital, Denpasar.

Results

We analyzed a total of 78 ECGs of obese adolescents (60% male). Subjects' mean age was 13.2 (SD 1.0) years. Most subjects were classified as obese [58 (68%)], while 25 (32%) subjects were classified as severe obesity. Pre-hypertension was found in 25 (32%) subjects, and hypertension was found in 18 (23%) subjects. Eight (10%) subjects had stage 2 hypertension. Characteristics of subjects are shown in **Table 1**.

Table 1. Subjects' characteristics

Clinical characteristics	(N=78)
Mean age (SD), years	13.2 (1.04)
Gender, n (%)	
Male	47 (60)
Female	31 (40)
Mean weight (SD), kg	82.6 (15.16)
Mean height (SD), cm	161.3(8.3)
Mean BMI (SD), kg/m2	31.5 (4.11)
Mean BMI Z-score (SD)	2.8 (0.6)
Nutritional status, n (%)	
Obese	53 (68)
Severe obesity	25 (32)
Blood pressure, n (%)	
Normotensive	35 (45)
Pre-hypertension	25 (32)
Hypertension grade I	10 (13)
Hypertension grade II	8 (10)

There were 29 (37%) subjects with abnormal ECGs. Sinus tachycardia was present in 13 (17%) subjects, and sinus arrhythmia was identified in 11 (14%) subjects. The mean QTc interval was 0.40 (SD 0.03) seconds, 8 (10%) patients experienced prolongation of the QTc interval. The mean PR interval was 0.156 (SD 0.02) seconds; five (6%) patients presented with prolongation of PR interval. There were no shifts of the P wave, QRS wave and T wave axes, changes of P wave morphology, low QRS voltage, T wave flattening, ventricular enlargement, or ST segment changes found in this study. Complete ECG characteristics are presented in **Table 2**.

Table 2. Electrocardiogram results

ECG characteristics	(N=78)
Rhythm, n (%)	
Normal sinus rhythm	53 (68)
Sinus tachycardia	13 (17)
Sinus bradycardia	1 (1)
Sinus arrhythmia	11 (14)
Mean heart rate (SD), beats/min	89.36 (16.4)
Mean PR interval (SD)	0.156 (0.02)
Prolonged PR interval, n (%)	5 (6)
Mean QRS duration (SD)	0.08 (0.10)
Mean QTc interval (SD)	0.40 (0.03)
Prolonged QTc interval, n (%)	8 (10)
Mean P wave amplitude (SD), mV	1.07 (0.34)
Mean P wave duration (SD), seconds	0.08 (0.01)
Normal ST segment, n (%)	78(100)
T wave, n (%)	
Normal T wave	78 (100)
ECG abnormalities, n (%)	29 (37)

Discussion

Obesity in adolescents is a known risk factor for cardiovascular disease, mortality, and sudden cardiac death. Studies in adults have reported several ECG phenomena associated with obesity, but data in children and adolescents are limited. The prevalence of heart abnormalities detected by ECG among healthy obese adolescents in our study was 37%, which was higher than a previous study (27%).[12] The difference may have been due to the subject populations, as the previous study by Sadoh *et al.* studied both overweight and obese adolescents, while we selected only obese adolescents as subjects.[12]

Abnormal heart rhythm, prolonged PR interval, and prolonged QTc interval were the three most common ECG abnormalities found in our study. Studies in adults have reported that various ECG changes were associated with obesity. These include left axis deviation, signs of left ventricular hypertrophy, bradycardia, and alterations of cardiac repolarization, like ST segment depression or T-wave inversion.[13,14] There are several hypotheses concerning possible influencing factors of obesity on ECG parameters. For example, increased cardiac output, thickening of epicardial and subcutaneous adipose tissue, influence of the autonomic nervous system, or hormonal and electrolyte disturbances may affect ECG parameters.[15]

Normal sinus rhythm refers to normal regular rhythm of the heart which is set by the sinoatrial node and may be assessed by ECG.8 Most subjects

in this study had normal sinus rhythm (68%). Sinus tachycardia occurred in 13 (17%) patients. This finding may have been due to anxiety, increased sympathetic activity, metabolic demand, and/or cardiac output. Other studies comparing obese and lean subjects have reported no significant difference in heart rate, but have reported higher heart rates in obese than in lean individuals. These differences rarely exceeded seven beats per minute and were not clinically important in most cases. Heart rate in obese subjects decreases with weight loss due to decreases in cardiac output, which is elevated in obesity, and occurs primarily because of a decline in stroke volume.[16]

Sinus arrhythmias occurred in 11 (14%) subjects. Of these, two subjects presented with ventricular extrasystoles (premature ventricular contraction). This finding was higher than previously reported by Frank *et al.* (4.8%).[13] Besides age and demographic differences, we suspect that the high prevalence of sinus arrhythmias in our study was due to the presence of physiological arrhythmias, which are commonly found in young people. This physiological phenomenon is called respiratory sinus arrhythmia. Respiratory sinus arrhythmia is heart rate variability in synchrony with respiration, resulting in shortened R-R interval during inspiration and prolongation during expiration.[17] Several longitudinal studies have demonstrated associations between obesity and cardiac dysrhythmias with increased risk of sudden cardiac death linked to increased adiposity.[17-19] The complex mechanisms leading to increased cardiac arrhythmias in obese individuals remain poorly understood. There has been an increased focus on the pathogenic role of adipose depots in abnormal electrical and structural remodeling leading to increased arrhythmogenicity in obese's hearts.[18]

Five (6%) subjects had prolongation of their PR interval. This finding was in agreement with a previous study that showed both overweight and obese children had significantly longer PR intervals compared to a control group of normoweight kids.6 Prolonged PR interval has been associated with an increased risk of heart failure, atrial fibrillation, and mortality.[6] Prolonged PR interval is also correlated with endothelial dysfunction and activation of vascular repair.[20] The PR interval tends to progressively increase with BMI and waist circumference. For each 5 unit increase in BMI, the PR interval increased by 2.4 ms. These results suggest that atrial remodeling (such as atrial fibrosis or autonomic remodeling) may occur in obesity.[21]

We found that 8 (10%) patients experienced prolonged QTc interval. This finding was similar to other studies which concluded that obesity was associated with QTc interval prolongation.[13,22,23] A study showed that the QTc interval of obese patients was longer than that of controls.[24] In contrast, other studies suggested that an association of obesity and QTc interval remained controversial.[6] The majority of previous studies had adult subjects, while the possible correlation between obesity and prolonged QTc interval in adolescents has not been studied in detail on a large-scale. The QT interval on the ECG represents depolarization and repolarization of the ventricles and is measured from the onset of the QRS complex to the end deflection of the T wave.[24] The QT interval is modulated by autonomic function, therefore, it is often corrected to be independent of heart rate. In our study, we used Bazzett's formula ($QTc = QT/\sqrt{RR}$) to correct the QT interval.[25] Prolonged QTc interval has been associated with life-threatening arrhythmias and an increased risk of sudden cardiac death.[23,25] Therefore, it is important to assess QTc intervals, especially in high-risk subjects.

There was no ventricular enlargement found in our subjects. This finding was consistent with previous studies.[6,9] In contrast, the evidence in adults presented so far supports the findings that the likelihood of LVH is higher in obese individuals. As such, obesity may increase the risk of LVH development over time.[9] The reason for the discrepancies among these studies is uncertain. The ECG criteria for left and right ventricular hypertrophy have a poor sensitivity, but strong specificity, in obese subjects. Thus, ECG has very limited use in the diagnosis of ventricular hypertrophy in obese subjects. Another theory suggested that the presence of ventricular hypertrophy in obese adults was associated with prolonged exposure to obesity, hypertension, diabetes mellitus, and dyslipidemia.[26]

Obesity in childhood and adolescence is considered to be a risk factor for death from cardiovascular disease and from all causes in adulthood. The Prospective Studies Collaboration analyzed data from 57 prospective studies with almost 900,000 participants. This study result showed that each 5 kg/m^2 BMI increment was associated with

about 40% higher vascular mortality (HR=1.41; 95% CI 1.37 to 1.45).[27]

A limitation of our study was its cross-sectional design, such that the associations between obesity and ECG parameters could be described, however, the long-term interaction between obesity and ECG variables was not analyzed. In addition, we did not evaluate serum electrolytes and markers of metabolic disturbance (for example, lipid profile and serum glucose) that could influence the ECG results. Subject were also not evaluated by echocardiography, which would have assessed cardiac function. Furthermore, the ECG changes in this study were relatively small, and it was unclear whether these ECG abnormalities had clinical significance. These issues require more investigation, as well as further and larger follow-up studies.

Electrocardiographic examination is a cost-effective method for detecting cardiac abnormalities. Periodic ECG examination of obese adolescents is recommended for early diagnosis and intervention to decrease the chances of sudden cardiac death and cardiovascular events. In conclusion, the prevalence of cardiac abnormalities based on ECG examination in obese adolescents was 37.2%, consisting of abnormal heart rhythm, prolonged PR interval, and prolonged QTc interval.

Conflict of Interest

None declared.

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