ejpmr, 2021, 8(4), 45-51

SJIF Impact Factor 6.222

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.ejpmr.com

Research Article

ISSN 2394-3211

EJPMR

IMPACT OF INCREASED BMI ON CARDIAC STRUCTURE AND FUNCTION IN ADOLESCENTS: A CROSS-SECTIONAL STUDY

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Article Received on 28/01/2021 **Article Revised on 17/02/2021** **Article Accepted on 09/03/2021**

ABSTRACT

Introduction: Obesity and overweight are the non-communicable epidemic in developed and developing countries and have grown in recent decades. Adolescent obesity is associated with a wide range of serious health complications and an increased risk of cardiovascular and other illnesses and death later in life. **Objective:** To study the impact of increased BMI on cardiac function in adolescents using 2D echocardiography. **Materials and Methods:** This cross-sectional study included 90 adolescents with matched sex and age -14(2) years were divided into three groups- 1) Normal weight (NW), 2) Overweight (OW) and 3) Obese (OB) based on the BMI (body mass index) percentile for age and sex. The subjects underwent anthropometric measurements to determine the BMI and record of blood pressure, heart rate, and 2D Echocardiography. The comparison of physical and cardiovascular parameters between the groups were done by Mann Whitney U test for the non-parametric data and student t-test for the parametric data. Statistical significance was considered to be $p \leq 0.05$. **Results:** The cardiovascular parameters including the pulse rate were statistically significant between NW Vs OW and NW Vs OB groups (NW Vs OW: $p<0.001$; and NW Vs OB: $p<0.001$), SBP (NW Vs OW: $p=0.003$; and NW Vs OB: $p<0.001$) and DBP (NW Vs OW: $p<0.001$; and NW Vs OB: $p<0.001$). The 2D echo recorded cardiac parameters including the LA diameter (NW Vs OW: $p<0.001$ and NW Vs OB: $p<0.001$), LV end diastolic diameter (NW Vs OW: $p=0.01$; and NW Vs OB: $p=0.001$), LV ejection fraction (NW Vs OW: $p=0.03$; and NW Vs OB: $p=0.001$) were statistically significant between NW Vs OW and NW Vs OB groups. Aortic diameter (NW Vs OB: $p=0.002$) was significant between normal weight and obese subjects only. LV end systolic diameter and fractional shortening were statistically insignificant between NW Vs OW and NW Vs OB groups. **Conclusion:** This scientific study has found a positive correlation between increased BMI and cardiac changes and recommends screening of overweight and obese children to identify and plan the preventive measures for the cardiovascular risk factors at an early stage.

KEYWORDS: Adolescent obesity, BMI, cardiac parameter, echocardiography.

INTRODUCTION

Obesity and overweight are the non-communicable epidemic both in developed and developing countries and increased in recent decades. The perception of a heavy child as a healthy child has changed with the evidence that obesity in childhood is associated with a wide range of serious health complications and an increased risk of cardiovascular and other illnesses and death later in life.[1] The prevalence of overweight and obesity among children and adolescents has risen dramatically from just 4% in 1975 to over 18% in 2016, and the rise has occurred similarly among both boys and girls. While just less than 1% of children and adolescents were obese in 1975 but more than 124 million children and adolescents (6% of girls and 8% of boys) were obese in 2016.[2]

According to the Center for Disease Control (CDC) definition, overweight classification in children over 2 years of age is defined as BMI ≥ to the 85th but less than the 95th percentile, and obesity as BMI ≥ to the 95th percentile of the reference range for age and sex.[3] The problem of overweight and obesity in the Kingdom of Saudi Arabia has increased in the last few decades with the changes brought about by modernization and economic prosperity that has created an obesogenic environment that promotes unhealthy eating, sedentary lifestyles, and weight gain.[4]

Obesity and overnutrition are strongly associated with chronic inflammation, metabolic perturbation, and a higher risk for several chronic diseases including cardiovascular disease, stroke, type 2 diabetes mellitus, and chronic liver disease. This metabolism-induced inflammation associated with obesity is termed metaflammation, and the western diet is a known risk factor.[5, 6] Overweight and obese children are more likely to stay obese into adulthood and to develop noncommunicable diseases (NCDs) like diabetes and cardiovascular diseases at a younger age. Obese children and adolescents suffer from both short-term and long-term health consequences. The structural and functional changes of the heart observed in obesity alone contribute to a deterioration in myocardial function.[7]

Atherosclerotic vascular lesions of patients with higher BMI values are more frequent and advanced compared to subjects with normal body weight.[8] A 10 kg rise in body weight increases the risk of coronary artery disease by 12% and at the same time, systolic blood pressure rises by 3 mmHg and diastolic by 2.3 mmHg as a consequence.[9] Structural and functional changes to the cardiovascular system in obesity include ventricular hypertrophy, diastolic dysfunction and aortic stiffness.[10,11]

Based on the data available, obesity is an independent risk factor of ST-elevation myocardial infarction (STEMI) developing at a young age but at the same time, excess weight can also be related to other vascular events. An increase in BMI by one unit causes a 4% rise in the risk of ischemic and a 6% rise in hemorrhagic strokes.[12, 13] A close correlation can be observed between heart failure and obesity. According to data from the Framingham Heart Study, the rise of BMI increases the risk of heart failure in the case of both men and women.[14] Abdominal obesity is associated with subclinical left ventricular dysfunction.[15]

Various studies have proven the relationship between obesity and atrial fibrillation. Obese patients have a higher risk for the development of atrial fibrillation compared to the normal weight population.[16-18] Obesity causes numerous anatomical and functional changes which play an important role in arrhythmogenesis. Left atrial dilation and dysfunction are known consequences of obesity. An increase in left atrial cross diameter has been shown to raise the chances of paroxysmal atrial fibrillation.[19]

Unlike other NCDs, overweight and obesity are preventable at the primary level. This scientific study has taken into consideration the study of cardiovascular parameters to understand the relationship between overweight and obesity and the cardiac risk involvement and to recommend obesity screening for early identification and plan for preventive measures and treatment.

MATERIALS AND METHODS

Design

A cross-sectional study was designed with a study population of 90 number (n=90) of subjects in the range of age group 11 years to 19 years of both sexes recruited from elementary and middle school. The study subjects were classified into three categories (n=30) each based on the Body Mass Index as normal weight (NW), Overweight (OW) and Obese (OB) individuals. The study was conducted after obtaining the ethical certificate from the institutional ethical committee and written consent obtained from the subjects and their guardians.

The subjects having ≥ 5th percentile of body mass index (BMI), according to the age- and gender-specific reference values of the 2007 CDC, WHO, without any history of chronic health issues, medications, and without any significant family history were considered for the study. The study subjects attended the sessions in the morning after a minimum 6 of hours fasting. The subjects underwent anthropometric measurements to determine the Body Mass Index and were divided into three categories. The subjects were made to rest for half an hour and then underwent recording of blood pressure, heart rate, and 2D Echocardiography.

METHODS

Height and Weight: Height and weight were measured using a wooden stadiometer and weighing machine.

Blood Pressure: Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured using a mercury sphygmomanometer.

Heart Rate: Electrocardiograms (ECG) using 3 bipolar silver-silver electrodes was utilized to measure heart rate (HR).

2D Echocardiography: Two-dimensional echocardiography is the most commonly used technique to assess cardiac structure and function in children. M-mode and two-dimensional images provide information on atrial dimensions and volumes, left ventricular (LV) wall thickness, LV dimensions, and global ventricular function (shortening fraction and ejection fraction). Transthoracic echocardiography with 2D imaging was done to record the cardiovascular structural and dynamic variables in real time. All subjects underwent transthoracic echocardiography, including tissue Doppler imaging and speckle tracking using a 2.5-MHz probe. Measurements were made in accordance with the latest guidelines. Experienced sonographers performed the echocardiography and reporting was verified by the cardiologist.

Statistical analysis

The data obtained were analyzed with SPSS (version 20; IBM Corporation, Armonk, NY, USA). The Shapiro-Wilk normality test was applied for all the descriptive parameters (Table. 1). The comparison of the anthropometric, physical and cardiovascular parameters between the groups were done by Mann Whitney U test for the non-parametric data and student t-test for the parametric data. Most of the data were non-parametric, hence Spearman's correlation test was applied to see the relation between obesity and cardiovascular parameters. Statistical significance was considered to be p≤0.05.

RESULTS

A total of 90 subjects (30 subjects in each group) with age -14(2) years, height - 158(8) cm and weight - 60.44±7.71 kg completed the study. The overall descriptive parameters with Shapiro-Wilk normality test of the participants are presented in Table 1. The anthropometric measurements weight, BMI, BMI percentile, waist circumference, weight height ratio was significant (p<0.001) between the groups in overall descriptive parameters for all the participants (Table 1).

Table 1. Participants (N=90) overall descriptive parameters with Shapiro-Wilk normality test.

Parameters	Mean±SD/Median (Interquartile Range)	Confidence interval CI (95%)	Shapiro-Wilk test P value
Age (Yrs)	14(2)	13.13-13.67	<0.001
Ht (cm)	158(8)	157.73-159.74	<0.001
Wt (Kg)	60.44±7.71	58.83-62.06	0.07
BMI	24.1(5.1)	23.4-24.55	0.002
BMI percentile	91(15)	84.71-89.11	<0.001
WC	78(21)	75.02-80.11	<0.001
WHtR	0.49(0.13)	0.47-0.5	0.002
PR	87.63±9.66	85.61-89.66	0.06
SBP	120(8)	118.20-120.49	0.01
DBP	78.32±5.28	77.22-79.43	0.07
LA (cm)	3(1)	3.09-3.35	<0.001
EDD (cm)	4(1)	4.06-4.31	<0.001
EF%	64(6)	64.12-65.25	<0.001
ESD (cm)	3(1)	2.47-2.68	<0.001
FS %	37(4)	35.51-36.56	<0.001
Aorta (cm)	2(1)	2.20-2.40	<0.001

***p≤0.05 considered as statistically significant.**

The cardiovascular parameters including the pulse rate (NW Vs OW: 80(9) - 89.5(13)/min, p<0.001; and NW Vs OB: 80(9) - 94(12)/min, p<0.001), SBP (NW Vs OW:117(5) -120(9) mmHg, p=0.003; and NW Vs OB:117(5) -121(9) mmHg, p<0.001) and DBP (NW Vs OW: 74.33±3.64 - 79.43±5.54 mmHg, p<0.001; and NW Vs OB:74.33±3.64 - 81.20±3.91, p<0.001) were statistically significant between NW Vs OW and NW Vs OB groups and these parameters were not comparable between OW and OB group (Table 2, 3 & 4).

The cardiac structural parameters including the LA diameter in cm (NW Vs OW: 3(1) -3(1), p<0.001; and NW Vs OB: 3(1) - 3.5(1), p<0.001), LV end diastolic diameter in cm (NW Vs OW: 4(0) - 4(2), p<0.01; and NW Vs OB: 4(0) – 4(1) , p<0.001), LV end systolic diameter in cm (NW Vs OW: 3(1) – 2.5(1), p=0.44; and NW Vs OB: 3(1) – 3(1), p=0.79), LV ejection fraction (NW Vs OW: 65(4) – 64(5), p=0.03; and NW Vs OB: 65(4) – 63(2), p=0.001), Fractional shortening in % (NW Vs OW: 36(5) – 37(7), p=0.1; and NW Vs OB: 36(5) – 37(4), p=0.43) and Aortic diameter in cm (NW Vs OW: 2(0) – 2(1), p=0.2; and NW Vs OB: 2(0) – 2.5(1), p=0.002) were statistically significant between NW Vs OW and NW Vs OB groups but these parameters were not associated significantly between OW and OB group (Table 4). All the obesity parameters are positively correlated with cardiovascular structural variables and their correlation were statistically significant (Table 5 & 6).

Table 2: Comparison of anthropometric and cardiac parameters between normal weight (n=30) and overweight (n=30) adolescents.

Parameters	Normal weight Median (Interquartile Range)/ Mean±SD	Overweight Median (Interquartile Range)/ Mean±SD	Mann-Whitney U test/student t test P value
Age (Yrs)	13.5(3)	14(4)	0.45
Ht (cm)	158(8)	157(7)	0.69
Wt (Kg)	52.67±4.27	61±4.29	<0.001
BMI	20.8(1.45)	24.2(2.15)	<0.001
BMI percentile	77.5(14)	91(5)	<0.001
WC	64(4)	78(6)	<0.001
WHtR	0.4(0.03)	0.49(0.04)	<0.001
PR	80(9)	89.5(13)	<0.001
SBP	117(5)	120(9)	0.003
DBP	74.33±3.64	79.43±5.54	<0.001
LA (cm)	3(1)	3(1)	<0.001
EDD (cm)	4(0)	4(2)	0.01
EF%	65(4)	64(5)	0.03
ESD (cm)	3(1)	2.5(1)	0.44
FS%	36(5)	37(7)	0.1
Aorta (cm)	2(0)	2(1)	0.2

Table 3: Comparison of anthropometric and cardiac parameters between normal weight (n=30) and obese (n=30) adolescents.

Parameters	Normal weight Median (Interquartile Range)/ Mean±SD	Obese Median (Interquartile Range)/ Mean±SD	Mann-Whitney U test/ Student t test P value
Age (Yrs)	13.5(3)	13.5(2)	0.85
Ht (cm)	158(8)	157.5(10)	0.98
Wt (Kg)	52.67±4.27	67.67±5.4	<0.001
BMI	20.8(1.45)	26.8(2.05)	<0.001
BMI percentile	77.5(14)	96(2)	<0.001
WC	64(4)	90(12)	<0.001
WHtR	0.4(0.03)	0.57(0.05)	<0.001
PR	80(9)	94(12)	<0.001
SBP	117(5)	121(9)	<0.001
DBP	74.33±3.64	81.20±3.91	<0.001
LA (cm)	3(1)	3.5(1)	<0.001
EDD (cm)	4(0)	4(1)	0.001
EF%	65(4)	63(2)	0.001
ESD (cm)	3(1)	3(1)	0.79
FS%	36(5)	37(4)	0.43
Aorta (cm)	2(0)	2.5(1)	0.002

Table 4: Comparison of anthropometric and cardiac parameters between overweight (n=30) and obese (n=30) adolescents.

Parameters	Overweight Median (Interquartile Range)/ Mean±SD	Obese Median (Interquartile Range)/ Mean±SD	Mann-Whitney U test/student t test P value
Age (Yrs)	14(4)	13.5(2)	0.46
Ht (cm)	157(7)	157.5(10)	0.78
Wt (Kg)	61±4.29	67.67±5.4	<0.001
BMI	24.2(2.15)	26.8(2.05)	<0.001
BMI percentile	91(5)	96(2)	<0.001
WC	78(6)	90(12)	<0.001
WHtR	0.49(0.04)	0.57(0.05)	<0.001

PR	89.5(13)	94(12)	0.05
SBP	120(9)	121(9)	0.39
DBP	79.43±5.54	81.20±3.91	0.15
LA (cm)	3(1)	3.5(1)	0.79
EDD (cm)	4(2)	4(1)	0.37
EF%	64(5)	63(2)	0.21
ESD (cm)	2.5(1)	3(1)	0.3
FS%	37(7)	37(4)	0.34
Aorta (cm)	2(1)	2.5(1)	0.06

Table 5. Spearman's correlation of obesity parameters with cardiovascular vital signs (N=90).

Variables		PR	SBP	DBP
Wt.	rho	0.477	0.308	0.520
	P value	<0.001	0.003	<0.001
BMI	rho	0.495	0.281	0.551
	P value	<0.001	0.003	<0.001
BMI percentile	rho	0.568	0.370	0.593
	P value	<0.001	<0.001	<0.001
WC	rho	0.599	0.383	0.541
	P value	<0.001	<0.001	<0.001
WHtR	rho	0.599	0.355	0.519
	P value	<0.001	0.001	<0.001

Table 6. Spearman's Correlation of obesity parameters with cardiovascular structural & functional variables (N=90).

Variables		LA (cm)	EDD (cm)	EF%	ESD (cm)	FS%	Aorta (cm)
Wt.	rho	0.473	0.283	-0.395	0.074	0.074	0.269
	P value	<0.001	0.007	<0.001	0.490	0.487	0.01
BMI	rho	0.490	0.343	-0.356	0.020	0.061	0.247
	P value	<0.001	0.001	0.001	0.849	0.571	0.019
BMI percentile	rho	0.473	0.315	-0.346	-0.014	0.038	0.249
	P value	<0.001	0.002	0.001	0.893	0.722	0.018
WC	rho	0.457	0.338	0.370	0.052	0.035	0.396
	P value	<0.001	0.001	<0.001	0.624	0.746	<0.001
WHtR	rho	0.444	0.337	-0.330	0.026	0.031	0.396
	P value	<0.001	0.001	0.001	0.808	0.775	<0.001

DISCUSSION

The present study was done with an aim to identify the association of adolescent's obesity and the functional changes in cardiac dynamic vital and structural factors using 2D echocardiography. The results of the study demonstrate that adolescent's obesity when compared with the age and sex-matched normal weight control group, is independently associated with the significant changes in the cardiovascular structural and functional variables.

This study revealed that in the overweight and obese group, the pulse rate, systolic blood pressure and diastolic blood pressure were significantly higher than in the normal weight group (Table 2, 3 and 4). These hemodynamic changes may be responsible for the myocardial morphological changes like hypertrophy and cardiac remodeling and over time the adaptive response concedes to cardiac dilatation and the ensuing remodeling process becomes maladaptive, leading to dysfunction in long term.[20, 21]

Concerning the structural changes, the left atrial diameter showed a significant difference between the normal weight and overweight adolescent subjects ($p<0.001$) and also between the normal weight and obese adolescent subjects ($p<0.001$). This association shows the early morphological changes start in childhood and the effect increases with the increase in the body mass index. These findings are in line with those reported by Mangner et al.[22] and Wouter and Franssen et al.[23] that the left atrial diameter is significantly higher in obese subjects.

The left ventricular structural and functional changes have shown that there was a significant increase in the left ventricular end-diastolic diameter in overweight and obese groups compared to the normal weight group. This was similar to the results of the study done by Mangner et al.[22], Putte-Katier et al.[24], Ghanem et al.[25] The present study, however, did not show any significant changes in the left ventricular end-systolic volume which correlates with these studies.[22, 24, 25]

The left ventricular ejection fraction has shown that there is a significantly reduced ejection fraction and this difference is observed between the normal weight and overweight adolescent subjects (p=0.03) and also between the normal weight and obese adolescent subjects (p=0.001). This finding of the study correlates well with the study done by Chinali et al. who found a significantly lower left ventricular ejection fraction in young obese subjects.[26]

Our study demonstrates that the ventricular fractional shortening did not show any significant correlation among the groups. This finding is in line with the finding of Mensah et al.[27] who found a significant negative association between mid-wall shortening fraction and central adiposity in black (but not white). A similar finding was reported by Gutin et al.[28] in their study that percent body fat correlated negatively with lower mid-wall ventricular shortening fraction. Rowland and Dunbar[29] also demonstrated in their study that there is a progressive decline in left ventricular shortening fraction with increasing BMI in young adolescent females.

Our study has shown that there is a significant association of the increased BMI in the obese group with the increased aortic wall thickness compared to the normal weight group (p=0.002), although there was no such significant association between the normal weight and overweight group. This finding is quite in agreement with the earlier report that there is a significant increase in aortic wall thickness among the obese group compared with the lean group.[30] These findings can be correlated with the previous pathologic studies that showed that atherosclerosis is an early process beginning in childhood, with fatty streaks observed in the aorta and the coronary and carotid arteries of children and adolescents.[31]

CONCLUSION

This scientific study has found a positive correlation between the increased BMI and the cardiac changes that supports the findings on the remodeling of the heart and vascular system with the increase in the BMI. The study recommends screening of obese children to identify and plan the preventive measures for the cardiovascular risk factors at an early stage.

CONFLICT OF INTEREST

We declare that we do not have any conflict of interest.

ACKNOWLEDGMENTS

This study was funded by a research grant (G-116-2020) from the University of Hafr Al Batin, Ministry of Education, Kingdom of Saudi Arabia. The authors would like to thank the administration and staff of the schools who participated in the study, along with the school children and their parents. The assistance provided by the team members is also gratefully acknowledged.

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