RESEARCH
www.commprac.com
ISSN 1462 2815

MEASUREMENT OF CAROTID INTIMA-MEDIA THICKNESS IN OVERWEIGHT, OBESE CHILDREN AND ITS ASSOCIATION WITH CARDIOVASCULAR RISK FACTORS

Dr. S. Priyanka [1], Dr. M.S. Balaji Kumar [2], Dr. K. V. Pugalendhi Raja [3]* and Dr. D Santhosh Reddy [4]

[1] Postgraduate, Department of Paediatrics,
Vinayaka Mission's Kirupananda Variyar Medical College and Hospitals,
Vinayaka Mission's Research Foundation (DU), Salem.
[2] Assistant Professor, Department of Paediatrics,
Vinayaka Mission's Kirupananda Variyar Medical College and Hospitals,
Vinayaka Mission's Research Foundation (DU), Salem.
[3] Professor and Unit Chief, Department of Paediatrics,
Vinayaka Mission's Kirupananda Variyar Medical College and Hospitals,
Vinayaka Mission's Research Foundation (DU), Salem.
*Corresponding Author Email: drkvpraja@gmail.com
[4] Sudheeksha Multispeciality Hospital, Nalgonda, Telangana.

DOI: 10.5281/zenodo.13164213

Abstract

BACKGROUND: Cardiovascular diseases (CVD) are primarily caused by atherosclerosis, which first manifests in children as damage to the arteries and its inner linings. Evidence suggested that childhood obesity and adult CVD risk factors are positively correlated. An independent CVD risk factor is the measurement of carotid intima-media thickness(cIMT), a noninvasive technique which is substitute or early marker for atherosclerotic changes. Its helps to find out the main risk factors that occurs mainly between obese children and teenagers who are more likely to experience an increase in cIMT. **OBJECTIVES:** The aim was to assess the association between Carotid artery intima-media thickness (cIMT) and risk factors of cardiovascular disease such as body mass index (BMI), waist circumference, blood pressure, fasting blood sugar, lipid profile among the study participants and to measure the cIMT among obese and overweight children of age 5 to 18 years. **MATERIALS AND METHODS:** It was a cross-sectional study in which 150 obese and overweight children of age group between 5 to 18 years seen in the OPD, Specialty Clinics and IP in various departments of the VMKV Medical College and Hospital over a period of 1 year and 10 months. Statistical analysis utilized windows 16.0. **RESULT:** The current study shows that 48% females and 52% males, which includes participants from age 5 to 18 years. The average age of the participants in the current study was 12.15 yrs. Participants in the part of study had a mean CIMT value of 0.58 and SD of 0.098. There was association between carotid intima media thickness and BMI, waist circumference, BP and biochemical parameters such as triglycerides, total cholesterol, serum LDL and serum HDL. **CONCLUSION:** The study implies that cardiovascular disease risk factors may exist from early age group and should be tested for in children. Hence, evaluating carotid arteries by doing carotid ultrasound is a very safe, practical, trustworthy procedure that can reveal information about common and internal cIMT. Early identification of high-risk individuals by screening for dyslipidaemia and other relevant risk factors can help in developing a proper preventative measure for cardiovascular disease.

INTRODUCTION

Cardiovascular diseases (CVD) are primarily caused by atherosclerosis, which first manifests in children as arterial damage to the arteries' inner linings.[1,2] Evidence suggested that childhood obesity and adult CVD risk factors are positively correlated.[3] Therefore, monitoring the development of atherosclerosis in obese children and adolescents may be aided by the assessment of subclinical markers of the disease.[4]

Over the past few decades, obesity in children and adolescents has become a major global problem. Childhood obesity has been linked to several cardiometabolic conditions including high blood pressure (BP), irregular glucose metabolism, dyslipidemia, and insulin resistance. However, not all obese people eventually develop metabolic disorders; these people are referred to as having "metabolically healthy obesity" (MHO).[5–7]

An independent CVD risk factor is the measurement of carotid intima-media thickness (cIMT), a noninvasive technique and substitute marker for early atherosclerotic changes.[8] Finding the main risk factors is important because children and teenagers with obesity are more likely to experience an increase in cIMT.[9]

MHO was not found to be associated with an increased risk of cardiovascular disease (CVD) when compared to metabolically healthy normal weight in some earlier studies in adults. However, accumulating evidence, including meta-analyses, suggests that MHO is not a benign condition and that it is linked to higher CVD risk and mortality in adults compared to adults with normal weight and a healthy metabolism.[10–13]

Atherosclerosis-related artery damage and dysfunction are strongly influenced by modifiable lifestyle factors, such as diet and exercise.[14] There is some evidence that dietary intakes in kids and teenagers are related to cIMT.[15–18] In a study by Giannini et al., pre-pubertal children with hypercholesterolemia had cIMT that significantly decreased after a 12-month intervention using a Mediterranean diet.[19]

Additionally, a study that examined the degree to which typical childhood dietary patterns predict adolescent cardiovascular phenotypes found that decade-long dietary patterns were not linked to resting heart rate but did not appear to affect macrovascular or microvascular structure or stiffness by mid-adolescence, suggesting an opportunity for prevention in the early years.[15] .

The carotid artery's combined intima and medial thickness (cIMT) is measured. B-mode ultrasound is the method most frequently used to measure cIMT. Hypertrophy of the intimal or medial layers, which are in charge of the onset and development of atherosclerosis, causes increase in cIMT.[20-23]

As a preliminary indicator of generalized atherosclerosis, the intima-media thickness (IMT) of the common carotid artery is measured on ultrasound images. Future cardiovascular morbidity and mortality are accurately predicted by this non-invasive method.[22]

Particularly in subjects who had been consistently obese from childhood to adulthood, increased carotid artery IMT (cIMT) in adults has been significantly linked to cardiovascular morbidities.[23]

The results of studies on the relationship between cIMT and various clinical and metabolic factors among overweight and obese children have varied. The data from the Cardiovascular Risk in Young Finns Study suggest that obesity indices measured in youth are significantly associated with increased carotid artery IMT and decreased elasticity in adulthood. T

hese relations are, at least, partly explained by significant tracking of obesity from youth to adulthood.[24]

With this above background, the present study has been conducted with the aim of measuring Carotid artery intima-media thickness (cIMT) among obese, and overweight children and to assess the association between cIMT and risk factors like body mass index (BMI), waist circumference, blood pressure, Fatty liver diagnosed with Ultrasonogram (USG), fasting blood sugar and lipid profile including HDL, LDL, total cholesterol and triglycerides.

Aim:

To assess the association between Carotid artery intima-media thickness (cIMT) and risk factors of cardiovascular disease.

Objectives:

1) To measure the Carotid artery intima-media thickness (cIMT) among obese, and overweight children of age 5 to 18 years.
2) To assess the association between cIMT and risk factors of cardiovascular disease like body mass index (BMI), waist circumference, blood pressure, fasting blood sugar and lipid profile among the study participants.

MATERIALS AND METHODS

Data for the cross-sectional study sourced all the obese and overweight children of age between 5 to 18 years who were seen in the OPD, Specialty Clinics, and hospitalised as IP in various departments of the VMKV Medical College and Hospital.

The study was conducted over a period of 1 year and 10 months, excluding Genetic Syndromes associated with obesity, Familial Dyslipidemias, Primary Hypothyroidism, Primary Hypertension and Children with Renal Disorders. Sample size of the study was 150 participants.

Following the parents informed consent, the first 150 obese and overweight children were enrolled and data such as Age, Gender, Socio-economic status, Height, Weight, Waist circumference, Blood pressure, Fasting blood sugar, Total cholesterol, Triglycerides, HDL, LDL, HDL:LDL ratio, Thyroid function tests and Mean Carotid Intima thickness were collected.

All data were analysed with a statistical software package of SPSS, version 16.0 for windows.

RESULT

The primary objective was to assess the association between Carotid artery intima-media thickness (cIMT) and risk factors of cardiovascular disease.

The study results were analysed using statistical software package SPSS version 16.0 for windows. The data were reported as the mean +/- SD or the median, depending on their distribution. Frequencies were exposed in percentages. chi-square test and fishers' exact test were used to assess the differences in categoric variables between group. A p value of <0.05 using a two tailed test was taken as being of significance for all statistical test.

The current study had got 48% females and 52% males, between 5 to 18 years. The mean age of the study population was found as 12.15 years. The gender was more or less evenly distributed among the study population at each age group.

69% hailing from urban area. The mean, maximum, minimum value and standard deviation of the data collected is as described in table 1.

Association between demographic, clinical variables and biochemical parameters using chi square test is as shown in table 2 and table 3.

Table 1

	Mean ± SD	Lower Bound	Upper Bound	Minimum	Maximum
Age	12.15±3.69	11.55	12.74	6	18
Gender					
Female	48%				
Male	52%				
Location					
Rural	31%				
Urban	69%				
BMI	24.54±1.60	24.28	24.79	22.26	28.36
WC	70.99±11.32	69.16	72.81	53	100
Systolic	104.67±11.22	102.86	106.48	90	120
Diastolic	65.13±9.61	63.58	66.68	50	80
FBS	94.29±16.58	91.61	96.96	56	136
Lipid Profile					
CHOL	171.35±42.90	164.43	178.27	115	311
TG	129.38±27.91	124.88	133.88	73	194
HDL	43.11±7.74	41.86	44.35	26	60
LDL	113.98±18.42	111.01	116.95	80	143
CIMT	0.58±0.098	0.57	0.60	0.31	0.76

Table 2: Association of Demographic & Clinical Variables with CIMT

		CIMT						
	Variables	**≤ 0.5**		**> 0.5**	**%**	**TOTAL**	**%**	**Sig**
	n	**26**		**124**		**150**		
Age	> 5 - ≤ 10	6	23%	42	34%	48	32%	
	> 10 - ≤ 15	11	42%	61	49%	72	48%	>0.05
	> 15 - ≤ 18	9	35%	21	17%	30	20%	
Gender	Female	13	50%	59	48%	72	48%	>0.05
	Male	13	50%	65	52%	78	52%	
Location	Rural	10	38%	37	30%	47	31%	>0.05
	Urban	16	62%	87	70%	103	69%	
BMI	Normal	13	50%	87	70%	100	67%	
	Over weight	13	50%	37	30%	50	33%	<0.05
WC	Low Risk	19	73%	104	84%	123	82%	
	High Risk	0	0%	13	10%	13	9%	<0.01
	Very High Risk	7	27%	7	6%	14	9%	
BP	LOW	0	0%	26	21%	26	17%	
	NORMAL	20	77%	80	65%	100	67%	<0.05
	HIGH	6	23%	18	15%	24	16%	
FBS	NORMAL	19	73%	105	85%	124	83%	>0.05
	HIGH	7	27%	19	15%	26	17%	

Table 3: Association of Bio-chemical Parameters with CIMT

		CIMT						
	Variables	**≤ 0.5**		**> 0.5**	**%**	**TOTAL**	**%**	**Sig**
	n	**26**		**124**		**150**		
Total Cholesterol	Desirable	6	23%	73	59%	79	53%	
	Border line	20	77%	20	16%	40	27%	<0.001
	High Risk	0	0%	31	25%	31	21%	
TG	Desirable	6	23%	10	8%	16	11%	<0.05
	Border line	7	27%	28	23%	35	23%	
	High Risk	13		86		99		
HDL	Desirable	0	0%	39	31%	39	26%	<0.001
	Border line	7	27%	55	44%	62	41%	
	High Risk	19		30		49		
LDL	Desirable	7	27%	56	45%	63	42%	
	Border line	6	23%	44	35%	50	33%	<0.01
	High Risk	13	50%	24	19%	37	25%	

There was association between carotid intima media thickness and BMI, waist circumference, BP and biochemical parameters such as triglycerides, total cholesterol, serum LDL and HDL with significant p-value <0.05 and there was no association between cIMT and age measurements, location, gender and fasting blood sugar which had p-value >0.05 as shown in the table 2 and 3.

DISCUSSION

Obesity in children and adolescents is a result of modern lifestyle changes, such as altered eating patterns, decreased physical activity and increased time spent watching television and playing video games. 80 percent of obese teenagers and about a third of obese youngsters continue to be obese as adults. It is well recognised that cardiovascular issues are favoured by atherogenic development starting in childhood. The most significant factor is the rising incidence of overweight and obesity in the world. Early detection makes atherosclerosis reversible and appropriate measures can be taken. High resolution B-mode ultrasonography is used to show an increase in IMT, arterial stiffness and endothelial dysfunction at the carotid artery.[25]

Comparison of basic characteristics of the study children with similar studies

The average age of the participants in the current study was 12.15 years, with a standard deviation of 3.69 years. Men made up most study participants (52 percent). The study participants had a mean BMI of 24.54 and a standard deviation of 1.60. Participants in the study had a mean fasting blood sugar of 94.29 mg/dl with a standard deviation of 16.58 mg/dl. Participants in the study had a mean total cholesterol reading of 171.35 with a standard deviation of 42.9. The study participants' mean triglyceride level was 129.38 with a standard deviation of 27.91. Participants in the study had an average HDL level of 43.11 with a standard deviation of 7.74. Participants in the study had a mean LDL level 113.98 with a standard deviation of 18.42.

378 toddlers participated in the cross-sectional, observational study that was carried out by Kumar Jain et al. The average age was 9.1 ±2.6 years, and 74.6 percent of the population was male. The average BMI was 18.7±3.9 kg/m2. The mean TG level was 96.85±2.7mg/dL and the mean cholesterol level was 142.1±58.7mg/dL. The mean LDL level was 84.2 mg/dL,

The mean HDL level and fasting blood sugar was 38.4mg/dl and 83.5±16.5 mg/dl.[26] Due to the different settings and different study population when compared to this study, all of the parameters are increased.

81 overweight or obese children and adolescents (age 13.6 ± 2.7 years, 62% females) who were hospitalised for weight loss were progressively recruited for the Schiel et al investigations in Germany. The average BMI was 31.2 ± 5.5 kg/m2.[27]

Sajja et al. in Tamilnadu carried out the hospital-based descriptive study and found that the mean age was 13.68 ± 2.4 years. The mean TG level was 113.42 ± 54.8mg/dL and the mean cholesterol level was 142.34±28.1mg/dL. Mean LDL levels were 95.46±27.9mg/dL and mean HDL levels were 43.18±13.9mg/dL. The blood sugar level at fasting was 89.16±17.6 mg/dL.[28]

Comparison of carotid-intima thickness among obese and overweight children with similar studies

The subjects in the current study had a mean Carotid-Intima thickness value of 0.58 and a standard deviation of 0.098. Mean CIMT was significantly higher (0.58mm), suggesting that preclinical atherosclerosis may have started in children at this young age. The present study's mean CIMT for overweight and obese children (0.58 mm) was similar to research by Elkiran et al. (0.53 mm), Ozguven et al. (0.57 mm), and Dabas et al (0.54 mm).[29-31]

Similar results were found by Kumar Jain et al. in their cross-sectional observational study, where they found that the average Carotid-Intima thickness of the study's participants was 0.58± 0.08 mm.[26]

In research by Schiel et al., conducted in Germany, participants' average Carotid-Intima thickness was 0.48± 0.09 mm.[27]

Sajja et al. in Tamilnadu carried out the hospital-based descriptive study where they found that the average Carotid-Intima thickness among youngsters was 0.5 ± 0.1 mm.[28]

Comparison of association between carotid-intima thickness and risk factors for cardiovascular disease with similar studies

The link between childhood BMI, BP and CIMT as risk factors for CVD has been the subject of certain investigations. CIMT, which is linked to coronary artery disease, stroke and the progression of coronary atherosclerosis can be utilised as a non-invasive method for the evaluation of subclinical atherosclerosis. An established predictor of early preclinical atherosclerosis is a higher CIMT. The causes of early carotid atherosclerosis in obese children haven't been fully understood, though. Recent research on overweight kids revealed considerably greater CIMT.

According to the results of the chi-square test, the mean Carotid-Intima thickness and risk factors such as BMI, waist circumference, BP, triglycerides, total cholesterol, serum LDL and serum HDL among obese and overweight children are positively associated. The test also suggested that there is a no link between the mean Carotid-Intima thickness and age measurements, gender differences and fasting blood sugar (FBS).

Similar results were seen in the cross-sectional observational study by Kumar Jain et al, which found that CIMT was substantially correlated with advancing age, rising blood pressure, and rising body mass index. The levels of HDL cholesterol, LDL, the LDL/HDL ratio, and the TC/HDL ratio were also found to be significantly correlated.[26]

Age, obesity, high blood pressure, and smoking were other significant risk factors for increased carotid intima media thickness in a study of young Gujarati children. Low HDL cholesterol and rising LDL cholesterol were the strongest present predictors of higher CIMT.

The Young Finns project, in which children aged 3 to 18 were re-examined 21 years later in adulthood, found a direct correlation between CIMT in adults and risk factors like high levels of LDL, SBP, BMI, and cigarette smoking.[24]

Ozcetin et al. did a prospective case-control analysis, which supports with the results of our investigation and found a positive connection between high BMI, high blood pressure, and increased carotid-intima thickness.[25]

Increased IMT in conjunction with additional cardiovascular risk factors in overweight and obese children, as well as the relationship between risk factors and BMI, strongly suggest that these conditions are important predictors of early atherosclerosis manifestations that have an impact on the structural and mechanical characteristics of major vessels. Atherosclerosis has been demonstrated in numerous studies to be a complex process that is sped up by metabolic problems, high blood pressure and low-grade inflammation. It appears that an increased mortality risk and risk for cardiovascular events in overweight and obese patients may be easily explained by the coexistence of numerous risk factors and an underlying chronic inflammatory process.

CONCLUSION

Participants in the study had a mean Carotid-Intima thickness value of 0.588 and a standard deviation of 0.097. According to the results of the chi-square test the mean Carotid-Intima thickness had association with BMI, waist circumference, blood pressure and biochemical parameters such as triglyceride levels, total cholesterol, serum LDL and serum HDL among obese and overweight children.

The test also suggested that there is a no association between the mean Carotid-Intima thickness and age measurements, gender and fasting blood sugar.

The study's findings imply that CVD risk factors may exist from an early age. Such risk factors should be tested for in children. When evaluating the carotid arteries, carotid ultrasound is a very safe, practical and trustworthy tool that can reveal information about both the common and internal carotid IMT. Early identification of high-risk individuals by screening for dyslipidaemia and other relevant risk factors can help in developing the proper preventative measures for cardiovascular disease.

Due to the rarity of cardiovascular clinical events in children, further cross-sectional research using standardised CIMT measurement technique is required to establish accurate normal values for age and gender in the paediatric population.

References

1) Frostegård J. SLE, atherosclerosis and cardiovascular disease. J Intern Med. 2005 Jun;257(6):485–95.

2) McGill HC, McMahan CA, Herderick EE, Malcom GT, Tracy RE, Strong JP. Origin of atherosclerosis in childhood and adolescence. Am J Clin Nutr. 2000 Nov;72(5 Suppl):1307S-1315S.

3) Burke V, Beilin LJ, Simmer K, Oddy WH, Blake KV, Doherty D, et al. Predictors of body mass index and associations with cardiovascular risk factors in Australian children: a prospective cohort study. Int J Obes (Lond). 2005 Jan;29(1):15–23.

4) Freedman DS, Patel DA, Srinivasan SR, Chen W, Tang R, Bond MG, et al. The contribution of childhood obesity to adult carotid intima-media thickness: the Bogalusa Heart Study. Int J Obes (Lond). 2008 May;32(5):749–56.

5) Hinnouho GM, Czernichow S, Dugravot A, Batty GD, Kivimaki M, Singh-Manoux A. Metabolically healthy obesity and risk of mortality: does the definition of metabolic health matter? Diabetes Care. 2013 Aug;36(8):2294–300.

6) Lo K, Wong M, Khalechelvam P, Tam W. Waist-to-height ratio, body mass index and waist circumference for screening paediatric cardio-metabolic risk factors: a meta-analysis. Obes Rev. 2016 Dec;17(12):1258–75.

7) NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. Lancet. 2017 Dec 16;390(10113):2627–42.

8) Urbina EM, Williams RV, Alpert BS, Collins RT, Daniels SR, Hayman L, et al. Noninvasive assessment of subclinical atherosclerosis in children and adolescents: recommendations for standard assessment for clinical research: a scientific statement from the American Heart Association. Hypertension. 2009 Nov;54(5):919–50.

9) Woo KS, Chook P, Yu CW, Sung RYT, Qiao M, Leung SSF, et al. Overweight in children is associated with arterial endothelial dysfunction and intima-media thickening. Int J Obes Relat Metab Disord. 2004 Jul;28(7):852–7.

10) Fan J, Song Y, Chen Y, Hui R, Zhang W. Combined effect of obesity and cardio-metabolic abnormality on the risk of cardiovascular disease: a meta-analysis of prospective cohort studies. Int J Cardiol. 2013 Oct 12;168(5):4761–8.

11) Kramer CK, Zinman B, Retnakaran R. Are metabolically healthy overweight and obesity benign conditions?: A systematic review and meta-analysis. Ann Intern Med. 2013 Dec 3;159(11):758–69.

12) Meigs JB, Wilson PWF, Fox CS, Vasan RS, Nathan DM, Sullivan LM, et al. Body mass index, metabolic syndrome, and risk of type 2 diabetes or cardiovascular disease. J Clin Endocrinol Metab. 2006 Aug;91(8):2906–12.

13) St-Pierre AC, Cantin B, Mauriège P, Bergeron J, Dagenais GR, Després JP, et al. Insulin resistance syndrome, body mass index and the risk of ischemic heart disease. CMAJ. 2005 May 10;172(10):1301–5.

14) Steinberger J, Daniels SR, Eckel RH, Hayman L, Lustig RH, McCrindle B, et al. Progress and challenges in metabolic syndrome in children and adolescents: a scientific statement from the American Heart Association Atherosclerosis, Hypertension, and Obesity in the Young Committee of the Council on Cardiovascular Disease in the Young; Council on Cardiovascular Nursing; and Council on Nutrition, Physical Activity, and Metabolism. Circulation. 2009 Feb 3;119(4):628–47.

15) Kerr JA, Gillespie AN, Gasser CE, Mensah FK, Burgner D, Wake M. Childhood dietary trajectories and adolescent cardiovascular phenotypes: Australian community-based longitudinal study. Public Health Nutr. 2018 Oct;21(14):2642–53.

16) Iannuzzi A, Licenziati MR, Vacca M, De Marco D, Cinquegrana G, Laccetti M, et al. Comparison of two diets of varying glycemic index on carotid subclinical atherosclerosis in obese children. Heart Vessels. 2009 Nov;24(6):419–24.

17) Özdemir R, Güzel O, Küçük M, Karadeniz C, Katipoglu N, Yılmaz Ü, et al. The Effect of the Ketogenic Diet on the Vascular Structure and Functions in Children With Intractable Epilepsy. Pediatr Neurol. 2016 Mar;56:30–4.

18) Doksöz Ö, Güzel O, Yılmaz Ü, İşgüder R, Çeleğen K, Meşe T, et al. The Short-Term Effect of Ketogenic Diet on Carotid Intima-Media Thickness and Elastic Properties of the Carotid Artery and the Aorta in Epileptic Children. J Child Neurol. 2015 Oct;30(12):1646–50.

19) Giannini C, Diesse L, D'Adamo E, Chiavaroli V, de Giorgis T, Di Iorio C, et al. Influence of the Mediterranean diet on carotid intima-media thickness in hypercholesterolaemic children: a 12-month intervention study. Nutr Metab Cardiovasc Dis. 2014 Jan;24(1):75–82.

20) Aminbakhsh A, Mancini GB. Carotid intima-media thickness measurements: what defines an abnormality? A systematic review. Clin Invest Med. 1999 Aug;22(4):149–57.

21) Strauss RS. Childhood obesity and self-esteem. Pediatrics. 2000 Jan;105(1):e15.

22) Polak JF, Szklo M, O'Leary DH. Associations of Coronary Heart Disease with Common Carotid Artery Near and Far Wall Intima-Media Thickness: The Multi-Ethnic Study of Atherosclerosis. J Am Soc Echocardiogr. 2015 Sep;28(9):1114–21.

23) Raitakari OT, Juonala M, Viikari JSA. Obesity in childhood and vascular changes in adulthood: insights into the Cardiovascular Risk in Young Finns Study. Int J Obes (Lond). 2005 Sep;29 Suppl 2:S101-104.

24) Ozcetin M, Celikyay ZRY, Celik A, Yilmaz R, Yerli Y, Erkorkmaz U. The importance of carotid artery stiffness and increased intima-media thickness in obese children. S Afr Med J. 2012 Mar 8;102(5):295.

25) Jain AK, Dani S, Jain P. Cardiovascular risk factors and their association with carotid intima media thickness in children in Western India. Int J Res Med Sci. 2018 Apr 25;6(5):1525.

26) Schiel R, Beltschikow W, Radón S, Kramer G, Perenthaler T, Stein G. Increased Carotid Intima-Media Thickness and Associations with Cardiovascular Risk Factors in Obese and Overweight Children and Adolescents. EUROPEAN JOURNAL OF MEDICAL RESEARCH. 2007;6.

27) Sajja V, Jeevarathnam D, James S, Rathinasamy J. A study on carotid artery intima–media thickness and metabolic risk factors in overweight and obese Indian children. Diabetol Int. 2019 Nov 12;11(2):142–9.

28) Elkiran O, Yilmaz E, Koc M, Kamanli A, Ustundag B, Ilhan N. The association between intima media thickness, central obesity and diastolic blood pressure in obese and owerweight children: A cross-sectional school-based study. International journal of cardiology. 2013;165(3):528–32.

29) Ozguven I, Ersoy B, Ozguven A, Ozkol M, Onur E. Factors affecting carotid intima media thickness predicts early atherosclerosis in overweight and obese adolescents. Obesity research & clinical practice. 2010;4(1):e41–8.

30) Dabas A, Thomas T, Gahlot M, Gupta N, Devasenathipathy K, Khadgawat R. Carotid intima-medial thickness and glucose homeostasis in Indian obese children and adolescents. Indian Journal of Endocrinology and Metabolism. 2017;21(6):859.