Relationship of anthropometric measures of fatness to serum lipid concentration in school children: A cross sectional study

*C S Yilgwan * [1] , G Yilgwan [2] , OO Ige [1] , E Yiltok [1] , II Abok [1] , C John [1] , CO Isichei [3] , SN Okolo [1]*

ABSTRACT
Background
Body fat distribution is associated with adverse health outcomes in adults. Research has shown that these usually begin in childhood. We thus set out to examine the relationship between body fat and the occurrence of adverse serum lipid profile in apparently healthy Nigerian School children.

Methods
This was a cross sectional observational study carried out between December 2013 and June 2014. Stratified random sampling was used in the recruitment process. All children present in school were eligible for selection except those on drugs known to predispose to dyslipidaemia. STATA version 14 was used for all statistical analysis. Descriptive statistics was used to calculate means and proportions while linear regression was used in investigating relationship between serum lipid concentration and measures of adiposity. Logistic regression was used to predict the relationship between measures of adiposity and adverse serum lipid status.

Results
A total of 240 school age children (56% females) aged 6-12 years (mean age=9.2±1.65 years) were studied. Total serum cholesterol was significantly associated with percent body fat(R=0.07; p=0.01) and hip circumference (R=0.02; p=0.023). Serum low density lipoprotein was significantly associated with percent body fat(R=0.05; p=0.04), waist circumference (R=0.02; p=0.01) and triceps diameter(R=0.06;p=0.04). Similarly, serum triglycerides was significantly associated with waist height ratio (R=0.64; p=0.04). No significant relationship was seen between high density lipoprotein cholesterol and any of the measures of adiposity. Logistic regression using those variables that have been consistently shown to be significantly related to serum lipid measures demonstrated only WC (OR=0.9; 95% CI=0.8-0.99) and triceps diameter (OR=1.26; 95% CI=1.02-1.56) significantly predicted bad total serum cholesterol status.

Conclusions
Subcutaneous adiposity and waist circumference are more reliable measures of serum lipids in school age children and thus more useful as a screening tool for dyslipidaemia during school health screening.

INTRODUCTION
Over the years, several published reports of the effect of body fat distribution on adverse health outcomes in adults have emerged. However, whether this adverse health outcomes resulting from lipid disorders can be replicated in children is a subject of ongoing research.[1-3] Likewise, alterations of levels of triglycerides and HDL-cholesterol seems to be

associated with markers of central obesity, measured with either simple anthropometric indices such as waist circumference, waist-hip ratio, waist-height ratio or with more advance techniques, such as computed tomography.[4,5] While tracking of blood lipids, obesity, and body fat distribution has been demonstrated to continue from childhood into adulthood,[6] studies in both adults and children have demonstrated that a more central (an android fat pattern) distribution of fat is associated with type 2 diabetes mellitus, increased cardiovascular disease risk profile, and other adverse outcomes.[7-9]

The effect of obesity and overweight on lipid distribution has been shown to depend largely on the index of measurement used.[10] Studies from Europe[11] and the US[12] have demonstrated that in obese children and adolescents, waist circumference, which is a good indicator of central obesity was associated with an unfavourable lipoprotein profile, mainly with increased levels of triglycerides and decreased levels of HDL-cholesterol independent of race, sex, age, weight, and height. Similarly, in school-aged children from Cyprus,[13] and South America,[14] waist circumference was the most significant predictor of triglycerides and HDL-cholesterol levels, when compared with BMI and waist to height ratio.

In Nigerian children, few studies report the relationship between central and truncal fat depots measured with simple anthropometric indices and levels of triglycerides and HDL-cholesterol.[15] Since adverse patterns of blood lipids and atherosclerosis itself begin in childhood, studies of population and individual differences in the early onset and progression through adolescence of risk factors are important.[16]

This current pilot study seeks to examine the relationship between body fat distribution and the occurrence of adverse serum lipid profile in apparently healthy Nigerian School children.

SUBJECTS AND METHODS
Study Design
This was a cross-sectional descriptive study.

Study Settings
The study was conducted in Jos South Local Government of Plateau State Nigeria between December 2012 and June 2013.

Study Participants
This consist of 241 primary school children aged 6 to 12 years old in two primary schools (1 public and 1 private primary school) in Hwolshe ward of Jos South Local Government Area of Plateau State, Nigeria.

A written informed consent was obtained from the parent or guardian of each participant of the study while each child's assent was sought before inclusion in the study despite parental consent. Each participant had the right to withdraw at any time during the study without any threat of punishment.

Sample size and Sample Population
The sample size was determined based on the 22.3% prevalence of cardiovascular risk in a previous study done among secondary school students in Jos, Nigeria.[17] Two schools were randomly selected from the list of 6 schools within the chosen ward. The school registers were used as the sampling frames in the selection of study subjects. A systematic sampling strategy was used with proportionate allocation.

Study Procedure
A self-administered questionnaire was used to obtain basic information on personal and family medical and social history from consenting parents or guardians during the school's parent's teacher association (PTA) meetings.

Anthropometric measurements
The heights of subjects were measured to the nearest one-tenth of a centimetre using the Healthline® stadiometer, according to standard protocols. Body weight was measured to the nearest one – tenth of a kilogram using the Healthline® standing scale which has an accuracy of 50g, also following standard measurement protocols.[18]

Waist circumference was measured to the nearest 0.1 cm at the mid-point between the lower costal border and the top of the iliac crest with the measurement

taken at the end of a normal expiration. [18, 19] Hip circumference was measured at the horizontal level of maximum circumference around the buttocks using an inextensible measurement tape with a 0.1-cm precision.[18, 19]

The percent body fat was measured with an Omron BIA device (Omron BF-400, Omron Healthcare Europe BV, Hoofddorp, Netherlands) following the manufacturer's instructions to the nearest 0.1%.

Triceps skinfold thickness was measured with the arm pendant, while subscapular skinfold thickness was measured just below the tip of the scapula.[20] Readings were taken 3 seconds after the caliper jaws were released. In addition, the mean of right- and left-sided measurements for each skinfold was then recorded.[18, 19] Standard (WHO) growth charts was used for interpretation of all anthropometric data so obtained.[20]

Laboratory Investigations
Following standard procedures, 5 ml of whole blood was collected from each child after an overnight fast of at least eight hours, and stored at 4°C until analysed. For children who had already had breakfast, blood collection was delayed until end of school to allow for the 8 hour fast. Blood was centrifuged, the serum was drawn into non-heparinized cryo-vials and then stored at -20°C until analysed for Total Cholesterol (TC), High-density Lipoprotein Cholesterol (HDL) and Triglycerides (TG) concentration. Serum lipid profile (TG, TC, and HDL) was determined using commercial test kits (Roche Diagnostics Ltd, Sussex, UK) at the Jos University Teaching Hospital Chemical Pathology Laboratory.

Derived Measures
Body mass indices were calculated from the heights and weights of the children, which were carefully measured according to standard protocols. Underweight was defined as body mass index (BMI) less than the 5th percentile for age and sex, obesity as BMI ≥95th percentile, and overweight as BMI ≥85th - 95th percentile for age and sex respectively.[18, 19]

Waist height ratio was calculated as child's waist circumference in centimetres divided by the height in centimetres. A ratio greater than 1.5 was considered abnormal and defined truncal obesity.

For the purpose of determining dyslipidaemia, the serum TC levels greater than 5.20 mmol/L, LDL-C levels greater than 3.4 mmol/L, TG levels greater than 3.6 mmol/L and HDL-C levels less than 0.9mmol/L were accepted as abnormal. Dyslipdaemia was defined as the presence of atleast one abnormal serum lipid concentration.[21]

Statistical Analysis
Data were analyzed using STATA version 14.0. Descriptive statistics of the baseline characteristics of study subjects was described using proportions, mean, standard deviation, frequency and percentage. Student t test was used to compare means of studied biochemical and physiological parameters. Linear Regression analysis was also carried out to evaluate relationships between serum lipid profile and body mass composition. Logistic regression analysis was used to determine the relationship between anthropometric measures and the odds of being dislypidaemic. A p-value of <0.05 at 95% confidence interval was considered statistically significant.

RESULTS
General Characteristics
A total of 241 school age children (56% females) aged 6-12 years (mean age=9.2±1.65 years) were studied.

The mean values of anthropometric and serum lipid parameters of the studied subjects are presented in Table 1. The male and female subjects were similar with regards to their mean ages, serum lipid values and most of the anthropometric measures. Males differ significantly from females in waist circumference (p=0.04), hip circumference (p=0.03), triceps skin fold thickness (p<0.001), subscapular skinfold thickness (p=0.004) and percent body fat (p=0.01).

Table 1 Mean Study Variables among 241 School Children

Parameter	Combined Mean±SD	Male Mean±SD	Female Mean±SD	P value
Age(yrs)	9.19±1.65	9.27±1.65	9.12±1.66	0.45
Weight(kg)	32.20±7.23	31.47±7.08	32.75±7.31	0.17
Height(cm)	138.14±10.29	137.87±9.57	138.38±10.03	0.68
BMI(Kg/m²)	16.68±2.16	16.38±1.98	16.91±2.27	0.06
WC(cm)	69.47±6.03	59.32±6.03	61.64±10.31	0.04
HC(cm)	69.47±7.73	68.27±7.19	70.39±8.02	0.03
WHR	0.87±0.09	0.87±0.04	0.88±0.11	0.59
WHtR	0.44±0.05	0.43±0.05	0.44±0.05	0.12
MUAC	19.17±3.03	18.88±3.06	19.40±3.00	0.18
Triceps (mm)	6.60±2.59	5.82±2.12	7.19±2.75	<0.001
Subscapular (mm)	8.73±4.60	7.76±4.75	9.47±4.35	0.004
% Body Fat	18.57±18.44	15.10±4.08	21.18±23.85	0.01
Serum Lipids				
Total cholesterol (mmol/L)	3.68±0.78	3.59±0.78	3.76±0.78	0.10
LDL-Cholesterol (mmol/L)	1.79±0.60	1.74±0.63	1.83±0.58	0.28
HDL-Cholesterol (mmol/L)	1.31±0.49	1.27±0.46	1.33±0.51	0.33
Triglycerides (mmol/L)	1.35±0.20	1.34±0.17	1.37±0.22	0.26

NB: BMI=body mass index, HC= Hip circumference, HDL= high density lipoprotein, LDL=Low density lipoprotein MUAC= mid upper arm circumference, WC= waist circumference, WHR= Waist-hip ratio, WHtR= waist – height ratio.

Prevalence in Lipid and Anthropometric Parameters

Overweight was more prevalent in females (10.8%) compared with males (Table 2). Similarly, gross obesity (10.4 %) and truncal obesity (24.5%) are more prevalent in females. On the other hand, abnormal total cholesterol (6.2%) and dyslipidaemia (6.2%) were more prevalent in males compared with females (Table 2).

Table 2 Prevalence of Abnormalities in Lipid and Anthropometric Measures

Parameter	Male Frequency (%)	Female Frequency (%)	Combine Frequency (%)
Overweight	20(8.3)	26(10.8)	46(19.1)
Gross Obesity	8(3.3)	25(10.4)	33(13.7)
Truncal Obesity	35(14.5)	59(24.5)	94(39.0)
Abnormal Total cholesterol	15(6.2)	7(2.9)	22(9.1)
Abnormal LDL-Cholesterol	1(0.4)	3(1.2)	4(1.6)
Abnormal HDL-Cholesterol	2(0.8)	0.0(0)	2(0.8)
Abnormal Triglycerides	0.0(0)	0.0(0)	0.0(0)
Dyslipidaemia	15(6.2)	8(3.3)	23(9.6)

NB: Dyslipidaemia=At least one abnormal serum lipid status.
HDL= high density lipoprotein, LDL=Low density lipoprotein, TC=total cholesterol

Regression Models of Anthropometric Measures and Serum Lipid Concentration

Linear regression analysis showed that TC (p=0.02) and LDL-C (p=0.04) significantly rise with a unit rise in percent body fat. Only LDL-C (p=0.04) significantly rises with unit rise in MUAC. Also, TC (p=0.003) and LDL-C (p=0.007) significantly falls with unit rise in WC. (Table 3)

Table 3 Relationship Between Serum Lipid Profile and Body Composition

Parameter	BMI (Kg/m²)			% Body Fat			MUAC			Triceps			WC			WHtR		
	Coeff	SE	P Value	Coeff	SE	P Value	Coeff	SE	P Value	Coeff	SE	P Value	Coeff	SE	P Value	Coeff	SE	P Value
TC	.009	.04	0.80	.007	.002	0.02	.02	.03	0.44	.04	.03	0.15	.04	.01	0.003	2.01	1.30	0.14
TG	.002	.009	0.79	.0009	.0007	0.90	-.001	.006	0.87	.003	.007	0.65	.004	.008	0.20	.88	.35	0.01
HDL-C	.01	.02	.66	.003	.002	0.09	-.008	.02	0.64	.02	.02	0.46	.01	.08	0.08	1.03	.87	0.24
LDL-C	.03	.03	0.28	.005	.002	.04	.03	.02	.05	.06	.03	.03	.03	.009	.007	.99	1.04	0.24

NB: BMI=body mass index, MUAC= mid upper arm circumference, WC= waist circumference, WHtR= waist – height ratio.

Logistic Regression Models of Anthropometric Measures by Dyslipidaemia Status

Waist-height ratio is significantly associated with the odds of having dyslipidaemia (OR=153.1, p=0.02). Similarly, WC is significantly associated with the odds of having dyslipidaemia (OR=1.83, p=0.006). Triceps skinfold thickness, MUAC and percent body fat were all associated with increased odds of having dyslipidaemia but were not statistically significant (Table 4).

Table 4 Logistic Regression Between Anthropometric Measures and Dyslipidaemia

Dyslipidaemia Status	Odds Ratio	Z	P Value	95% CI
BMI (Kg/m²)	0.87	-0.84	0.40	0.60 to 1.22
%Body fat	1.06	0.77	0.44	0.91 to 1.24
MUAC(cm)	1.05	0.44	0.69	0.84 to 1.32
WC(cm)	1.83	2.75	0.006	1.74 to 1.95
WHtR	153.1	2.29	0.02	7.81 to 301.1
Triceps Skinfold diameter(mm)	1.16	1.24	0.22	0.02 to 937.1

NB: BMI=body mass index, MUAC= mid upper arm circumference, WC= waist circumference, WHtR= waist – height ratio.

DISCUSSION

Cardiovascular health is emerging as an important public health issue not only in adults but also in children especially since the origin of CVD has been established in childhood.[3,7,8] With an increasing school enrolment rate in Nigeria, the school environment presents an important opportunity for studies that may serve as surrogates of the burden and characteristics of the problem in the general population.[15, 17]

In the current study, we found females to have on average wider waist line and hips compared with their male counterparts in contrast to what has been generally reported.[22] In addition, females were found to have higher triceps and subscapular skinfold thickness, a measure of subcutaneous fat deposition and greater percent body fat similar to what has been reported by Shaw et al[22] among multiracial British school aged children where subcutaneous fat was shown to rise steadily with age in girls compared with boys.

The prevalence of overweight and truncal obesity was found to be higher in females compared with their male counterparts similar to what has been

reported among Nigerian,[15] Brazillia[23] and Sudanese Children.[24] Though the overall prevalence of 13.7% is higher than the 0-5% prevalence previously reported in Nigeria, it however is in tandem with current reports from other developing countries suggesting the possible effect of nutritional transition in Nigeria[25] probably due to the effects of globalization.

Prevalence of abnormal total cholesterol and low density cholesterol were significantly higher in females while high density cholesterol was significantly lower in males. Also, dyslipidaemia, which was defined as the presence of atleast one abnormal serum lipid status was more prevalent in males compared with females. The 9.5% prevalence of dyslipidaemia found in this study though lower than what was reported in children from developed economies is still high enough to warrant concern in a population hitherto plagued by infectious diseases and under nutrition.[26,27] Dyslipidaemia is said to be the main stimuli for the atherosclerotic changes that is seen in coronary heart diseases with resultant increase mortality from myocardial infarction.[2,5]

Both WHtR and WC showed significant association with serum lipids compared with BMI further underscoring their importance as measures of adiposity and supporting the current preference for employing them instead of BMI as screening tools or surrogate indicators of measure of adiposity especially in children.[28-30] Furthermore, since both of them measure central obesity which is specifically related to the presence of cardiovascular risk factors they will be more useful tools in significant prediction of dyslipidaemia as shown in the current study.[27-30]

Although malnutrition is prevalent in African countries including Nigeria, childhood overweight and obesity and by extension dyslipidaemia is increasingly assuming an important public health concern in many African countries.[32,33] Dyslipidaemia has been shown to be more associated with overweight and obesity resulting in pathologic evidence of accelerated atherosclerosis commonly reported in autopsy studies in childhood.[17,29,31] Research reveal the important role of lipoprotein in determining atherosclerotic changes especially as it relates to changes in its main fractions – HDL, LDL and TG.[10,11,22] While the root cause of atherogenesis is multifactorial, however, subendothelial retention of LDL-containing lipoproteins are said to be an important pathway to atherosclerosis in childhood.[10,11,22] Thus, the results of the current study serve as an important mirror for potential interventions in reducing the burden of overweight and obesity in children thereby slowing the rate of developing atherosclerosis in childhood in order to reduce the burden of adult onset CVD with its complications later in life.[29,30,33]

STRENGTH AND LIMITATIONS
The strength of this study is being able to measure fasting lipid levels in school age children limiting the potential fluctuation of serum lipids with dietary intake. Secondly, it serves as an important first step in investigating the relationship between anthropometry and serum lipids in a population of apparently healthy children potentially revealing the extent of the problem in the general population. However, being a cross sectional study representing a small segment of the Nigerian population, it will be too simplistic to make generalization. In addition, a causal link cannot be established for the observations noted.

CONCLUSION
Waist height ratio and waist circumference can be helpful parameters in identifying school age children with adverse blood-lipids profile especially where population based screening is considered.

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REFERENCES
1. James PT. Obesity: the worldwide epidemic. Clinics in dermatology. 2004 Aug 31; 22(4):276-80.

2. D'Adamo E, Guardamagna O, Chiarelli F, Bartuli A, Liccardo D, Ferrari F, Nobili V. Atherogenic dyslipidemia and cardiovascular risk factors in obese children. International journal of endocrinology. 2015 Jan 12; 2015

3. Beyerlein A, Toschke AM, Schaffrath Rosario A, von Kries R. Risk Factors for obesity: further evidence for stronger effects on overweight compared to normal-weight children and adolescents subjects. PLoS One 2011; 6(1):e15739.

4. Gómez-Díaz RA, Wacher-Rodarte NH. Childhood obesity and dyslipidemia. Revista medica del Instituto Mexicano del Seguro Social. 2013 Dec; 52:S102-8.

5. Franssen R, Monajemi H, Stroes ES, Kastelein JJ. Obesity and dyslipidemia. Medical Clinics of North America. 2011 Sep 30; 95(5):893-902.

6. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. Jama. 2014 Feb 26;311(8):806-14

7. Bibbins-Domingo K, Coxson P, Pletcher MJ, Lightwood J, Goldman L. Adolescent overweight and future adult coronary heart disease. New England Journal of Medicine. 2007 Dec 6; 357(23):2371-9.

8. Dixon JB. The effect of obesity on health outcomes. Molecular and cellular endocrinology. 2010 Mar 25; 316(2):104-8.

9. Coutinho T, Goel K, de Sá DC, Carter RE, Hodge DO, Kragelund C, Kanaya AM, Zeller M, Park JS, Kober L, Torp-Pedersen C. Combining body mass index with measures of central obesity in the assessment of mortality in subjects with coronary disease: role of "normal weight central obesity". Journal of the American College of Cardiology. 2013 Feb 5; 61(5):553-60.

10. Montali A, Truglio G, Martino F, Ceci F, Ferraguti G, Ciociola E, Maranghi M, Gianfagna F, Iacoviello L, Strom R, Lucarelli M. Atherogenic Dyslipidemia in Children: Evaluation of Clinical, Biochemical and Genetic Aspects. PloS one. 2015 Apr 21; 10(4):e0120099.

11. Gröber-Grätz D, Widhalm K, De Zwaan M, Reinehr T, Blüher S, Schwab KO, Wiegand S, Holl RW. Body mass index or waist circumference: which is the better predictor for hypertension and dyslipidemia in overweight/obese children and adolescents? Association of cardiovascular risk related to body mass index or waist circumference. Hormone Research in Paediatrics. 2013 Sep 6; 80(3):170-8.

12. Freedman DS, Serdula MK, Srinivasan SR, Berenson GS. Relation of circumferences and skinfold thicknesses to lipid and insulin concentrations in children and adolescents: the Bogalusa Heart Study. Am J Clin Nutr 1999; 69:308–317.

13. Savva SC, Tornaritis M, Savva ME et al. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. Int J Obes Relat Metab Disord 2000; 24:1453–1458.

14. Maffeis C, Pietrobelli A, Grezzani A, Provera S, Tato L. Waist circumference and cardiovascular risk factors in prepubertal children. Obes Res 2001; 9:179–187.

15. Ene-Obong H, Ibeanu V, Onuoha N, Ejekwu A. Prevalence of overweight, obesity, and thinness among urban school-aged children and adolescents in southern Nigeria. Food and Nutrition Bulletin. 2012 Dec; 33(4):242-50.

16. Lenfant C. Task force on Research in Epidemiology and Prevention of Cardiovascular Diseases. Circulation 1994; 90:2609 ± 2617.

17. Madu EF, Animasahun BA, Okolo SN, et al. Cardiovascular disease risk factors among secondary school students in an urban community in Nigeria. Nig Qt J Hosp Med. 2014; 24:57-62.

18. National Health and Nutrition Examination Survey (NHANES). Anthropometry Procedures Manual, January 2007. Retrieved from http://www.achi.net/BMIContent/Documents/101007_Height_and_Weight_Measurement_Training_Manual1with_revisions.pdf.

19. Cole TJ, Bellizzi MC, Flegal KM, et al. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 2000;320:1240–1243

20. WHO Multicentre Growth Reference Study Group 2006.WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development. Geneva: World Health Organization. Accessed 20th June 2015.

21. Horsley L. AAP Clinical report on lipid screening in children. Am Fam Physician. 2009 Apr 15; 79(8):703-705.

22. Shaw NJ, Crabtree NJ, Kibirige MS, Fordham JN. Ethnic and gender differences in body fat in British

schoolchildren as measured by DXA. Archives of disease in childhood. 2007 Oct 1; 92(10):872-5.

23. De Assis MA, Rolland-Cachera MF, Grosseman S, de Vasconcelos FA, Luna ME, Calvo MC, Barros MV, Pires MM, Bellisle F. Obesity, overweight and thinness in schoolchildren of the city of Florianopolis, Southern Brazil. European journal of clinical nutrition. 2005 Sep 1; 59(9):1015-21.

24. Nagwa MA, Elhussein AM, Azza M, Abdulhadi NH. Alarming high prevalence of overweight/obesity among Sudanese children. European journal of clinical nutrition. 2011 Mar 1; 65(3):409-11.

25. Senbanjo IO, Oshikoya KA, Olutekunbi OA, Njokanma OF. Body fat distribution of children and adolescents in Abeokuta, Southwest Nigeria. American journal of physical anthropology. 2013 Apr 1; 150(4):647-54.

26. Ribas SA, Santana da Silva LC. Anthropometric indices: predictors of dyslipidemia in children and adolescents from north of Brazil. Nutr Hosp. 2012 Jul 1; 27(4):1228-35.

27. Kit BK, Kuklina E, Carroll MD, Ostchega Y, Freedman DS, Ogden CL. Prevalence of and trends in dyslipidemia and blood pressure among US children and adolescents, 1999-2012. JAMA pediatrics. 2015 Mar 1; 169(3):272-9.

28. Martin-Calvo N, Moreno-Galarraga L, Martinez-Gonzalez MA. Association between Body Mass Index, Waist-to-Height Ratio and Adiposity in Children: A Systematic Review and Meta-Analysis. Nutrients. 2016 Aug 20; 8(8):512.

29. Nawarycz T, So HK, Choi KC, Sung RY, Li AM, Nelson EA, Gazicki-Lipman M, Ostrowska-Nawarycz L. Waist-to-height ratio as a measure of abdominal obesity in southern Chinese and European children and adolescents. International Journal of Obesity. 2016 Jan 27.

30. Zheng W, Zhao A, Xue Y, Zheng Y, Chen Y, Mu Z, Wang P, Zhang Y. Gender and urban–rural difference in anthropometric indices predicting dyslipidemia in Chinese primary school children: a cross-sectional study. Lipids in health and disease. 2016 Apr 30; 15(1):87.

31. Steyn NP, Mchiza ZJ. Obesity and the nutrition transition in Sub-Saharan Africa. Annals of the New York Academy of Sciences. 2014 Apr 1; 1311(1):88-101.

32. Ende C, Twisk JW, Monyeki KD. The relationship between BMI and dietary intake of primary school children from a rural area of South Africa: the Ellisras longitudinal study. American Journal of Human Biology. 2014 Sep 10; 26(5):701-6.

33. Campbell F, Conti G, Heckman JJ, Moon SH, Pinto R, Pungello E, Pan Y. Early childhood investments substantially boost adult health. Science. 2014 Mar 28; 343(6178):1478-85.