Clinical Nutrition ESPEN xxx (xxxx) xxx

Contents lists available at ScienceDirect

Clinical Nutrition ESPEN

journal homepage: http://www.clinicalnutritionespen.com

Original article

Anthropometric status and lipid profile among children and adolescents: Changes after 18-month follow-up

Priscila Ribas de Farias Costa [a, b, *], Mônica Leila Portela de Santana [a, b],
Luana de Oliveira Leite [b], Nadjane Ferreira Damascena [b],
Carina Marcia Magalhães Nepomuceno [b], Jamile Rafaela Pereira da Silva Barreto [b],
Sanjay Kinra [c], Ana Marlúcia Oliveira Assis [a, b]

[a] *Department of Nutrition Science, School of Nutrition, Federal University of Bahia, Basílio da Gama Street, 40110-907, Canela, Salvador, BA, Brazil*
[b] *Postgraduate Program in Food, Nutrition and Health, School of Nutrition, Federal University of Bahia, Basílio da Gama Street, 40110-907, Canela, Salvador, BA, Brazil*
[c] *Department of Non-communicable Disease Epidemiology, London School of Hygiene and Tropical Medicine, Keppel Street, WC1E 7HT, London, UK*

ARTICLE INFO

Article history:
Received 5 March 2019
Accepted 3 October 2019

Keywords:
Dyslipidaemia
Children
Adolescents
Cohort
Anthropometric status
Lipid profile

SUMMARY

Background & aims: Overweight children and adolescents are more likely to evolve with high cholesterol, be obese adults and develop cardiovascular disease. The objective of this study was to identify the influence of anthropometric status on the changes in the lipid profile of children and adolescents during an 18-month follow-up period.

Methods: A cohort study involving 540 boys and girls from 7 to 15 years of age was conducted over 18 months' follow-up. The outcome variables were the lipid indicators and the principal exposure variable was anthropometric status, measured by different indicators. A generalized estimating equation (GEE) approach was used to identify the associations of interest.

Results: Irrespective of age, sex, socio-economic status, physical activity and diet, for each gain of 1 cm in the waist circumference (WC) mean in the adjusted model, triglyceride levels increased by a mean of 0.5 mg/dl ($p < 0.000$) and there was an increase of 0.21 mg/dL in the total cholesterol after the 18-month period. The increase of 0.1 in the mean body mass index (BMI) Z-score promoted a gain of 2.7 mg/dL in the triglycerides mean levels ($p < 0.000$) and an increase of 1.5 mg/dL in the total cholesterol mean levels ($p = 0.014$) after the follow-up period. Regarding the waist-to-height ratio (WHtR) and conicity index (CI), an increment of 40.6 mg/dL ($p = 0.02$) and of 30.1 mg/dL ($p = 0.01$) was observed in the triglycerides' mean when the participants increased 0.1 in the WHtR mean and CI mean, and the same was observed in the total cholesterol mean, with an increase of 45.4,g/dL ($p = 0.02$) and 19.3 mg/dL ($p = 0.03$), for each indicator, respectively. Changes of the traditional anthropometric indicators (WC and BMI) did not promote variations in the mean levels of LDL-cholesterol. HDL-cholesterol was not influenced by the changes in the anthropometric indicators.

Conclusions: At the baseline, a higher triglyceride mean and lower levels of HDL-c were observed in children and adolescents with altered anthropometric status for all measures. Mean triglyceride and total cholesterol levels are influenced by changes in the anthropometric status, regardless of the measure, after 18 months of follow-up. However, for LDL-cholesterol, it was observed that changes in the traditional anthropometric indicators (WC and BMI) did not promote variations in the mean levels of this biochemical variable, while HDL-c was not influenced by changes in any of the anthropometric indicators.

Abbreviations: BMI, body mass index; CVD, cardiovascular disease; GEE, generalized estimating equation; WC, Waist Circumference; WHtR, Waist-to-height; CI, Conicity index; FFQ, food frequency questionnaire; LDL-c, low-density lipoprotein cholesterol; HDL-c, high-density lipoprotein cholesterol; TC, total cholesterol; NHANES, National Health and Nutrition Examination Survey; NCEP, National Cholesterol Education Program; AIC, Akaike's Information Criterion; QICc, quasi-likelihood under independence model criterion.

[*] Corresponding author. Basílio da Gama Street, 401140-090, Canela, Salvador, BA, Brazil. Fax: +55 71 3283 7700.
E-mail address: priscilarf@yahoo.com.br (P.R.F. Costa).

https://doi.org/10.1016/j.clnesp.2019.10.004

Please cite this article as: Costa PRdF et al., Anthropometric status and lipid profile among children and adolescents: Changes after 18-month follow-up, Clinical Nutrition ESPEN, https://doi.org/10.1016/j.clnesp.2019.10.004

1. Introduction

Obesity in adolescence has acquired epidemic proportions throughout the world, leading to a situation of health risk and increased morbidity and mortality [1]. In developed countries, 23.8% of boys and 22.6% of girls were overweight in 2013. In developing countries, rates went from 8.1% to 12.9% for males and 8.4%–13.4% for females between 1980 and 2013 [2]. Recent evidence still indicates a significant increase in the prevalence of abdominal obesity in adolescents of both sexes [3–5].

As well as the excess weight, the prevalence rates of dyslipidaemia among children and adolescents are increasing over the years, ranging from 3% to 40% [6–9]. The rising rates of childhood overweight may result in a higher prevalence of dyslipidaemia in childhood and adulthood, once studies have identified a strong and positive association between these morbidities [10]. The Bogalusa Heart Study group showed that children who are overweight are more likely to be obese adults and to evolve with elevated cholesterol levels and cardiovascular disease (CVD) [11]. Studies have also demonstrated that increased body fat is associated with unfavourable lipid and lipoprotein profiles in children and adolescents [12], since the inadequate expansion of subcutaneous adipose tissue is an important cause of lipid overflow into the visceral and non-adipose tissues, an event called lipotoxicity, which can promote cardiometabolic consequences [13].

However, longitudinal studies evaluating the influence of anthropometric status on changes in the lipid profile in children and adolescents are scarce. Identifying lipid alterations in the paediatric population according to changes in the body composition is important as the epidemiology of obesity evolves. Taking this into consideration, the present study seeks to consolidate information about these associations through the use of a robust epidemiological design aiming to identify the influence of anthropometric status on changes in the lipid profile of children and adolescents during an 18-month follow-up period.

2. Materials and methods

2.1. Study design, population and sample size

This is a cohort study undertaken over an 18-month period. The sample included 540 boys and girls aged 7 to 15. The selection of pupils was conducted using a simple random sampling. The Municipal Education Department of a municipality of Bahia, Brazil provided a list of all registered elementary school children. Ten public, urban and part-time schools were selected, and 54 pupils from each school were assessed in 2006. The main study was conducted with the aim of evaluating risk factors for cardiovascular disease in children and adolescents. Pitangueiras et al. [14] described the baseline results of the primary study.

The present sample size had a power of 95% for detecting a change of 10% in total cholesterol over 18 months of follow-up, considering mean cholesterol levels of 158.0 mg/dl (SD 30.4). For detecting a 10% change in LDL-cholesterol (LDL-c), the power was 94%, considering a mean of 91.4 mg/dl (SD ± 25.9), while for HDL-c the power was 99%, considering a mean of 47.5 mg/dl (SD ± 10.5). In the case of triglycerides, the study had a power of 96% for detecting a change of 10% over 18 months, taking into consideration a mean of 92.1 mg/dl (SD 10.5) [15].

2.2. Criteria for non-inclusion

The following criteria for non-inclusion were established for this study: children or adolescents being treated with anticonvulsants, thiazides, diuretics and corticosteroids, or any medications for chronic renal failure, diabetes mellitus, liver disease or hyperthyroidism or that are capable of altering LDL-c, HDL-c, triglycerides or total cholesterol levels [16]. Also defined as criteria for non-inclusion were pregnancy, breastfeeding and showing any physical handicaps that would make it difficult for an anthropometric assessment to take place. However, none of the children or adolescents showed any of these conditions.

2.3. Data collection and definition of variables

Socio-demographic, clinical and anthropometric data was measured by trained nutritionists. The samples of blood were collected by a laboratory technician qualified in collecting blood from children and adolescents. The main exposure variables (Body Mass Index, Waist Circumference, Waist-to-height ratio and Conicity index), the co-variables and the outcome variables of the study were all measured at baseline and after 18 months of follow-up.

2.4. Anthropometric data

According the parameters of Lohman, Roche and Martorell, 1988 [17], the height was measured using a stadiometer (Leicester Height Measure, SECA, Hamburg, Germany) and the weight was evaluated by a portable digital scale (Filizola, São Paulo, Brazil). The measure of the waist circumference (WC) was evaluated by an inelastic tape of fibreglass with scale in centimetres. All measures were performed in duplicate and the mean between the two values was adopted as the final score. The body mass index (BMI)-for-age was evaluated using guidelines from World Health Organization growth reference data for a population of 5–19 years of age [18]. The BMI-for-age was rated as healthy weight (<percentile 85) and excess weight (>percentile 85), for statistical analysis.

The waist-to-height ratio (WHtR) [19] was assessed by WC (centimetres) and height (centimetres). The measures of body weight, height and WC were used to provide the conicity index (CI), using as reference the mathematical equation of Valdez [20]. The values for this index vary from 1.0 to 1.73. Values close to 1.00 represent a morphological profile similar to that of a perfect cylinder, predicting low risk for the onset of cardiovascular and metabolic diseases, and values close to 1.73 suggest a body shape similar to a double cone, indicating high risk for cardiovascular morbidities [20]. However, there is a lack of consensus about the cut-off point of WC [21], WHtR and CI in children and adolescents, so we adopted the 90th percentile value of the sample from this study to estimate abdominal fat.

2.5. Demographic, socio-economic, clinical and lifestyle-related data

A structured questionnaire was applied to obtain other information. The demographic data included the child or adolescent's sex and age. Maternal education was evaluated separately of the socio-economic index. The score of socio-economic index included the sum of the number of rooms in the house, the main form of lighting, how many individuals were living in the house, and also the occupation of the head of the family. Furthermore, data such as the water supply to the home, the source of drinking water and how rubbish and household waste were disposed of were used to calculate the environmental index. For these two indexes, the answers were awarded scores that ranged from 0 to 4, with 0 representing poorest conditions and 4 the best. To classify the socio-economic and environmental indexes we established a range from a minimum of 0 to a maximum of 16 points. The results were defined into tertiles. The participant who scored on the first or second tertile was defined as being in the risk category and the third tertile placed them in the protected category.

Please cite this article as: Costa PRdF et al., Anthropometric status and lipid profile among children and adolescents: Changes after 18-month follow-up, Clinical Nutrition ESPEN, https://doi.org/10.1016/j.clnesp.2019.10.004

A structured questionnaire to measure the physical fitness level was evaluated using the frequency of physical activity during the week. The questionnaire did not include the once-a-week exercise performed at school as part of the governmental curriculum. Classification was divided into active, predominantly inactive or sedentary.

2.6. Dietary information

The assessment of dietary intake was evaluated using a food frequency questionnaire (FFQ) adapted from an instrument previously validated in children and adolescents in the same town [22]. The FFQ showed 96 food items with 8 possible responses about intake: daily, once a week, 2, 3, 4, 5 and 6 times a week and rarely/never. The methodology suggested by Monteiro, Riether and Burini (2004) [23] was used to identify the overall dietary intake of each food item. Then, the score was obtained for every food group by multiplying the weekly frequency of intake by the number of weeks in a month and dividing it by the number of days in a month. Scores varied from 1 (daily intake) to zero (rarely or never consumed) and were classified as tertiles.

Two dietary groups were separated after the scores had been calculated, based on the composition of the food items, as follows: a) group of food items characterized with food with high saturate fat foods, sodium chloride and simple sugars (the first and second tertiles were the risk category); b) group of food items that are sources of fibre, complex B vitamins and minerals, meats, fish, dark-green vegetables, whole and enriched grain products, legumes and citrus fruits (as protection category, the third tertile was adopted).

2.7. Biochemical assessment

After fasting for at least 12 h, 10 ml of sample blood were collected in the morning by venous puncture into a sterile, disposable Vacutainer (BD®) with no anticoagulant. The serum used for the biochemical tests were separated by means of the centrifugation of the blood samples at 3000 rpm for 10 min. Following the tests, aliquots of serum were stored in Eppendorf tubes at −20 °C.

Triglycerides, low-density lipoprotein cholesterol (LDL-c), high-density lipoprotein cholesterol (HDL-c), and total cholesterol (TC) levels in the serum from the blood samples were assessed using the enzymatic method via a Hitachi analyser 704. Specific details on the assessment of these cholesterol parameters are discussed thoroughly in a previous publication [24].

The evaluation of LDL-c serum levels followed the Friedewald formula, using the following levels of total cholesterol (TC), triglycerides (TG), and high-density lipoprotein cholesterol (HDL-c): LDL-c (mg/dL) = TC (mg/dL) - HDL-c (mg/dL) - TG (mg/dL)/5. The analyses of the biochemical parameters were made by trained technicians. The assessment was performed at the municipal reference laboratory, which was made available to the researchers by the Municipal Health Department.

2.8. Identification of the variables

The outcome variables of this study were total cholesterol, LDL-c, HDL-c and triglycerides. The measurements of these variables occurred at the baseline and after 18-months of follow-up. For the descriptive data analysis, these variables were used categorically. Given that there is evidence that mean total cholesterol, LDL-c, HDL-c and triglyceride serum levels change significantly as a function of age and sex [25], age and sex were taken into account for their classification. Then, we adopted the cut-off points of those variables suggested by Jolliffe and Janssen (2006) for adolescents from 12 to 19 years of age (percentile by sex and gender) [26]. For schoolchildren under 12 years of age, for whom age standardized cut-off points are as yet unavailable, the recommendation of the National Health and Nutrition Examination Survey (NHANES) was used to classify HDL-c (less than 40 mg/dL), while the definitions proposed by the National Cholesterol Education Programme (NCEP) were used to classify TC ($\geq$200 mg/dL), LDL-c ($\geq$130 mg/dL) and triglycerides ($\geq$100 mg/dL).

2.9. Statistical analysis

The cross-sectional analysis was conducted using data from the baseline of the study and the longitudinal analysis was performed using data from the baseline, 12th month and 18th month of follow-up.

Prevalence rates were used to describe the distribution of the outcome variables (serum lipids) and principal exposure variables (anthropometric indicators) in the study population. All the variables were compared according to the sex using Pearson's chi-square test for categorical variables. The baseline mean levels of serum lipids were compared according to the anthropometric indicators using the mean comparison test.

To evaluate the influence of anthropometric status, according to different indicators, on the changes in lipid profile over the 18-month follow-up period, generalized estimating equations (GEE) models were constructed. These are considered as appropriate models for continuous response variables and repeated measures, reflecting the association between the response and the independent variables, considering the correlation and interdependency between the measurements at each moment in time [27].

The corrected quasi-likelihood under independence model criterion (QICc) was used to evaluate the fit of the model to the data. The QICc criterion is an adaptation of Akaike's Information Criterion (AIC) used for the GEE analyses. The QICc is calculated based on the comparison of the quasi-likelihood of the model of independence with the complete model. The lower the QICc, the better the fit of the model [28].

A GEE model was constructed for each outcome variable (total cholesterol, LDL-c, HDL-c and triglycerides) continuously and as a function of time, according to each principal exposure variable (waist circumference, WHtR, CI and BMI). Initially, a univariate analysis was conducted and the variables with a p-value < 20% were selected. These variables and others identified as potential confounders in the bivariate analysis were included in the model. Variables associated either with the exposure and the outcome variable, as expressed by a change of 10% or more in the measure of association compared to the measure in the reduced model, were considered potential confounders [27]. The variables that were significant at 5% remained in the final model.

The analyses were performed using the statistical software package Stata/IC for Mac, version 12.0 (StataCorp, College Station, TX, USA).

2.10. Ethical aspects

The study protocol was approved by a committee of the School of Nutrition, Federal University of Bahia, in accordance with Brazilian regulations. The reference number of the project authorization is 03/06. First, the parents and/or guardians received a written authorization with the study aims. After receiving the appropriate information about the study, the parents or guardians signed the term allowing participation in the study.

3. Results

The socio-economic, anthropometric and biochemical characteristics of the population in the beginning of the study are shown in

Please cite this article as: Costa PRdF et al., Anthropometric status and lipid profile among children and adolescents: Changes after 18-month follow-up, Clinical Nutrition ESPEN, https://doi.org/10.1016/j.clnesp.2019.10.004

Table 1. The proportion of low maternal education differed according to sex, being greater in female children and adolescents (61.5%; p = 0.01). Prevalence rates of 18.9%, 17% and 16.9% were found for abdominal fat, considering different indicators (WC, WHtR and CI, respectively). The prevalence rates of altered serum lipid levels varied from 18.7% (for low HDL-c level) to 25.6% (for hypertriglyceridaemia). For the high TC levels the prevalence was greater in female children and adolescents (p < 0.01). Furthermore, the prevalence of low HDL-c levels differed according to sex, with a rate of 23.4% being recorded for the boys compared to 15.3% for the girls (p = 0.02) (Table 1).

The baseline lipid mean levels of this study population according to the anthropometric indicators are described in Table 2. A greater mean level of TC was found in children and adolescents without excess weight, considering the BMI (p < 0.00). Lower mean levels of HDL-c were found in children and adolescents with altered anthropometric status for all the measurements. In addition, greater mean levels of triglycerides were found for all the altered status of the anthropometric measures evaluated in the study. No other statistically significant differences were found.

Table 3 shows the crude and adjusted results of the GEE analysis for the changes in the lipid profile. For all models, the adjustment was made for the block of socio-demographic (sex, age, maternal education), physical activity and diet-related variables. Changes in the levels of triglycerides, TC, LDL-c and HDL-c over the 18-month follow-up period are described as follows.

3.1. *Changes in triglycerides*

For each increase of 1 cm in the WC mean of children and adolescents, there was an increment of 0.4 mg/dL in the triglycerides mean levels after 18 months of follow-up. After the adjustment of the model, this increment rose to 0.5 mg/dL (p < 0.000). The same relationship was observed for the BMI. An increase of 0.1 in the BMI Z-score mean promoted a gain of 2.7 mg/dL in the triglyceride mean levels after adjustments (p < 0.000).

With regard to the WHtR, an increment of 40.6 mg/dL (p = 0.02) was observed in the triglyceride mean levels when the participants increased 0.1 in the WHtR mean, after the follow-up period. We must consider that this variation is related to the characteristic of this variable, which, as a ratio (WC/Height), requires a very significant increase in the numerator (WC) to promote an increase of 0.1 in the ratio.

In the case of the CI, it was observed that for each increase of 0.1 in this index mean there was an increment of 30.1 mg/dL (p = 0.01) in the triglyceride mean levels after 18 months' follow-up. This outstanding change is also related to the nature of this variable, which requires an important increase in the WC (numerator) to promote an elevation of 0.1 in its mean.

The fit of the models was good, as evaluated by the QICc, with a reduction in this indicator in the final models compared to the crude models (Table 3).

3.2. *Changes in total cholesterol (TC)*

The anthropometric changes, according to different indicators, also promoted important variations in the TC mean levels of the children and adolescents, after the follow-up period. For the WC indicator, there was an increase of 0.21 mg/dL in the total cholesterol for each gain of 1 cm in the WC mean in the adjusted model, after the 18-month follow-up period (p = 0.02). Considering the BMI, an increment of 0.1 in its Z-score mean promoted an increase of 1.5 mg/dL in the TC mean levels (p = 0.014) after the sequence period.

For the WHtR and CI it was observed that an increment of 0.1 in the mean of these variables was followed by an increase of 45.4 g/dL (p = 0.02) and 19.3 mg/dL (p = 0.03) in the TC mean, respectively.

All the models were well fitted considering the reduction of the QICc in the final models, compared to the crude models (Table 3).

3.3. *Changes in LDL-cholesterol*

For the LDL-cholesterol, it was observed that the changes of the traditional anthropometric indicators (WC and BMI) did not promote variations in the mean levels of this biochemical variable. However, the changes in the WHtR and CI variables prompted negative variations in the LDL-cholesterol after the follow-up period, as shown in Table 3.

In the final models, each increase of 0.1 in the mean of WHtR and CI promoted an increment of 34.8 mg/dL (p = 0.015) and 19.4 mg/dL (p = 0.02) in the LDL-cholesterol mean levels, respectively.

The fits of both models were good, considering the reduction of the QICc in the final models, compared to the crude models.

3.4. *Changes in HDL-cholesterol*

This biochemical variable was not influenced by the changes in the anthropometric indicators, as shown in Table 3.

4. Discussion

In this study we investigated the prevalence of excess weight, abdominal obesity, lipid alterations and the influence of anthropometric status on the changes of the lipid profile in children and adolescents after an 18-month follow-up period.

Our results indicated high prevalence of abdominal obesity independent of the anthropometric index used and are in agreement

Table 1
Baseline socioeconomic, anthropometric and biochemical characteristics of children and adolescents according to sex. Municipality of Bahia, Brazil, 2006.

	Overall N (%)	Female N (%)	Male N (%)	P-value[a]
Age ≥ 12 years old	211 (42.9)	124 (43.2)	87 (42.4)	0.87
Maternal Education < 6 years	248 (56.5)	155 (61.5)	93 (49.7)	0.01
Socioeconomic Index <3rd tercile	322 (70.7)	191 (72.1)	131 (68.9)	0.47
Waist circumference ≥ P90	93 (18.9)	56 (19.5)	37 (18.0)	0.68
Waist-to-height Ratio ≥ P90	84 (17.0)	52 (18.1)	32 (15.6)	0.47
Conicity Index ≥ P90	83 (16.9)	46 (16.1)	37 (18.0)	0.55
BMI excess weight	100 (20.3)	58 (20.2)	42 (20.5)	0.94
High total cholesterol levels	108 (21.9)	80 (27.9)	28 (13.7)	<0.01
High LDL-c levels	96 (19.5)	60 (20.9)	36 (17.6)	0.35
Low HDL-c levels	92 (18.7)	44 (15.3)	48 (23.4)	0.02
High triglyceride levels	126 (25.6)	82 (28.6)	44 (21.4)	0.07

N = 492 HDL: high-density lipoprotein; LDL: low-density lipoprotein.
[a] Significant p-value for Pearson's Qui-squared test.

Please cite this article as: Costa PRdF et al., Anthropometric status and lipid profile among children and adolescents: Changes after 18-month follow-up, Clinical Nutrition ESPEN, https://doi.org/10.1016/j.clnesp.2019.10.004

Table 2
Mean comparison test of baseline lipid variables in children and adolescents according to anthropometric indicators. Municipality of Bahia, Brazil, 2006.

Variable	Total cholesterol (mg/dl)	P-value	LDL-c (mg/dl)	P-value	HDL-c (mg/dl)	P-value	Triglycerides (mg/dl)	P-value
WC[a]		0.18		0.33		<0.00		<0.00
≥P90	167.3		97.2		50.7		113.1	
<P90	170.8		95.7		53.2		96.1	
BMI[b]		<0.00		0.20		<0.00		<0.00
Altered	165.5		96.4		49.9		95.4	
Normal	177.4		99.1		56.2		113.0	
WHtR[c]		0.13		0.35		0.03		<0.00
≥P90	167.2		97.2		50.9		117.2	
<P90	171.3		95.8		52.8		95.2	
CI[d]		0.29		0.22		0.04		<0.00
≥P90	167.5		97.4		50.8		113.3	
<P90	169.6		94.7		52.7		96.0	

Sample size: 492; HDL: high-density lipoprotein; LDL: low-density lipoprotein.

[a] Waist circumference.

[b] Body Mass Index.

[c] Waist-to-height ratio.

[d] Conicity Index.

Table 3
Generalized estimating equation models for the relationship between anthropometric status, evaluated according to waist circumference (WC), body mass index (BMI), waist-to-height ratio (WHtR) and CI, and serum lipids changes over 18 months of follow-up. Municipality of Bahia, Brazil, 2006–2008.

	Triglycerides Coef (95% CI); p[a] value	Total cholesterol Coef (95% CI); p[a] value	LDL-c Coef (95% CI); p[a] value	HDL-c Coef (95% CI); p[a] value
WC				
Crude model	0.40 (0.20–0.55); <0.000	0.17 (0.3–0.6); 0.01	0.10 (−0.03–0.2); 0.139	0.01 (−0.03–0.07); 0.428
QIC_c[b]	125.449	918.912	746.138	127.319
Final model[c]	0.51 (0.32–0.70); <0.000	0.21 (0.2–0.36); 0.02	0.07 (−0.1–0.53); 0.328	0.03 (−0.03–0.09); 0.340
QIC_c[b]	117.850	907.938	740.102	124.545
BMI				
Crude model	2.93 (1.53–4.32); <0.000	1.6 (0.4–2.8); 0.009	0.63 (−0.4–1.7); 0.247	0.52 (0.07–0.96); 0.02
QIC_c[b]	125.607	918.031	746.576	126.884
Final model[c]	2,70 (1.32–4.06); <0.000	1.5 (0.3–2.7); 0.014	0.56 (−0.5–1.67); 0.305	0.4 (0.06–0.83); 0.109
QIC_c[b]	117.394	903.906	740.051	116.641
WHtR				
Crude model	35.1 (−1.30–71.4); 0.06	54.0 (25.6–82.4); <0.000	40.3 (13.0–67.7); 0.004	10.6 (1.67–19.5); 0.06
QIC_c[b]	126.217	913.271	74.328	126.921
Final model[c]	40.6 (5.3–75.9); 0.02	45.4 (14.9–75.8); 0.02	34.8 (6.7–62.8); 0.015	7.9 (−0.99–16.1); 0.09
QIC_c	56.585	902.212	73.781	58.060
CI				
Crude model	17.6 (−4.8–40.1); 0.123	17.6 (−1.5–36.7); 0.07	18.3 (1.1–35.5); 0.03	−0.87 (−7.9–6.23); 0.809
QIC_c[b]	127.013	920.412	744.986	127.328
Final model[c]	30.1 (7.0–53.1); 0.01	19.3 (1.3–37.3); 0.03	19.4 (2.0–36.8); 0.02	−2.66 (−10.0–4.7); 0.478
QIC_c[b]	122.145	910.903	740.130	124.596

Sample Size: 492 WC: Waist circumference; BMI: Body Mass Index; WHtR: Waist-to-height ratio; CI: Conicity Index; HDL: high-density lipoprotein; LDL: low-density lipoprotein.

[a] Generalized Estimating Equations – GEE.

[b] Adjusted by sex, age, sociodemographic, physical activity and dietetic variables.

[c] QIC_C: corrected quasi-likelihood under independence model criterion for GEE.

with the findings of other investigations [29–31]. Moreover, it was possible to identify that the elevation in triglyceride levels was the most prevalent form of alteration of the lipid profile in the studied population. At the baseline, higher mean triglycerides and lower levels of HDL-c were observed in children and adolescents with altered anthropometric status for all measures.

The study developed by Lozano et al. (2016) [32], evaluating the screening for dyslipidaemia in a paediatric population from two large U.S. studies, identified a higher prevalence of this morbidity in overweight (11.5%) and obese (16%) children and adolescents. Also, they detected that fifty per cent of children and adolescents with dyslipidaemia will have dyslipidaemia as adults, which highlights the importance of routinely screening children and adolescents for dyslipidaemia and excess weight.

Considering the longitudinal influence of anthropometric measurements on the lipid profile, the increase of adiposity, independent of the index used, elevated triglycerides and TC mean levels after the 18-month follow-up. However, for the LDL-c, it was observed that changes in the traditional anthropometric indicators (WC and BMI) did not promote variations in the mean levels of this biochemical variable. Only the increase in the WHtR and in the CI elevated their levels after the follow-up period. And, the HDL-c was not influenced by changes on any anthropometric index evaluated during the follow-up.

The use of anthropometric indicators for the evaluation of abdominal obesity is important because they are likely to be useful in the early detection of risk factors for cardiovascular diseases [33,34]. Despite being a good indicator of overall obesity, BMI alone may not be a good predictor of cardiovascular risk in children and adolescents, because it does not seem to adequately reflect the changes in body composition during adolescence [35].

Abdominal adiposity, especially visceral fat, may be involved in changes in lipid variables, since this type of fat has been strongly associated with cardiometabolic alterations, such as: hypertriglyceridaemia, increased availability of free fatty acids, reduction of clearance of triglyceride-rich lipoproteins, increased synthesis

Please cite this article as: Costa PRdF et al., Anthropometric status and lipid profile among children and adolescents: Changes after 18-month follow-up, Clinical Nutrition ESPEN, https://doi.org/10.1016/j.clnesp.2019.10.004

and secretion of VLDL from the liver, release of proinflammatory cytokines by adipose tissue, insulin resistance and inflammation of the liver, presence of small and dense LDL-c particles and reduced levels of HDL-c [36].

Abdominal fat has low levels of mono and polyunsaturated fatty acids and high concentrations of trans and saturated fatty acids. In situations of excess visceral adipose tissue there is stimulation of lipolysis resulting in excess free fatty acids in the liver. There is, therefore, greater hepatic glucose production in addition to an increase in circulating levels of triglycerides and a reduction in HDL-c levels [37,38].

Cross-sectional studies have identified the association between the presence of excess adipose tissue in the abdominal region and high levels of total cholesterol and triglycerides in children and adolescents [33,39,40]. However, longitudinal studies evaluating the influence of anthropometric status on changes in the lipid profiles of children and adolescents are scarce, and the only longitudinal study identified in the databases consulted, evaluating male adolescents, showed that half of the boys had HDL-c levels above the values recommended for this parameter, but these values showed a decline with the increase of the BMI and advance of the pubertal stage [40]. The result of the cited study differs from that found in the present study, thus requiring further investigation of this lipid variable over time in this population. Confirmatory studies are required to provide sufficient scientific evidence to clarify the association between excess body weight and high levels of serum lipids in children and adolescents. The findings of the present study contribute to this and highlight the importance of anthropometric parameters in predicting early dyslipidaemias.

The possible limitation of this study is the follow-up period (18 months) that may not be adequate to identify the adiposity variation during the entire puberty period. However, the data from this study are reliable, since they come from a research with a robust methodological design, a cohort study, whose structure and monitoring were well defined, besides having insignificant number of losses. Appropriate statistical methods were also used for in-depth data analysis. Therefore, the findings found in this study corroborate the results of other authors, although the majority are cross-sectional, confirming the importance of studying the influence of overweight on changes in the lipid profile in children and adolescents over the time.

In this regard, these conclusions highlight the clinical and epidemiological importance of excess weight in the paediatric age group and support the recommendation of the implementation of prevention and control actions of weight gain, and consequently, dyslipidaemias, since they are important risk factors for cardiovascular diseases and other chronic diseases.

Grants and funding

This study was supported by Bahia State Foundation for the Support of Research, grant number FAPESB-PPSUS 001/2007.

Author contributions

Design study (Costa, PRF; Assis, AM; Santana, MLP), practical performance (Costa, PRF; Assis, AM; Santana, MLP), data analysis (Costa, PRF; Kinra, S), preparation manuscript (Costa, PRF; Assis, AM; Santana, MLP; Kinra, S; Leite, LO; Damascena, NF; Nepomuceno, CMM; Barreto, JRPS), critical review manuscript (Costa, PRF; Assis, AM; Santana, MLP; Kinra, S; Leite, LO; Damascena, NF; Nepomuceno, CMM; Barreto, JRPS).

Declaration of Competing Interest

We declare that we have no conflicts of interest.

Acknowledgements

The authors gratefully acknowledge all the children and adolescents who participated in the study and the team who gave great contributions during data collection.

References

[1] Abreu S, Santos R, Moreira C, Santos PC, Mota J, Moreira P, et al. Food consumption, physical activity and socio-economic status related to BMI, waist circumference and waist-to-height ratio in adolescents. Public Health Nutr 2014;17(8):1834–49.

[2] Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. The Lancet 2014;384:766–81.

[3] Hassapidou M, Tzotzas T, Makri E, Pagkalos I, Kaklamanoset I, Kapantais E, et al. Prevalence and geographic variation of abdominal obesity in 7- and 9-year-old children in Greece; world health organization childhood obesity surveillance initiative 2010. BMC Public Health 2017;17:126.

[4] Bozza R, de Campos W, Bacil ED, Barbosa Filho VC, Hardt JM, da Silva PM. Sociodemographic and behavioral factors associated with body adiposity in adolescents. Rev Paul Pediatr 2014;32:241–6.

[5] Silva DA, Pelegrini A, Silva AF, Grigollo LR, Petroski EL. Abdominal obesity and associated factors among adolescents: comparison of two economically different Brazilian regions. Arq Bras Endocrinol Metabol 2012;56:291–9.

[6] Al-Shehri SN, Saleh ZA, Salama MM, Hassan YM. Prevalence of hyperlipidemia among Saudi school children in Riyadh. Ann Saudi Med 2004;24(1):6e8.

[7] Faria-Neto JR, Bento VFR, Baena CP, Olandoski M, Gonçalves LGO, Abreu GA, et al. ERICA: prevalência de dislipidemia em adolescentes brasileiros. Rev Saúde Pública 2016;50(supl. 1):10s.

[8] 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 Pediatr 2015;169(3):272–9.

[9] Yang S, Hwang JS, Park HK, Lee HS, Kim HS, Kim EY, et al. Serum lipid concentrations, prevalence of dyslipidemia, and percentage eligible for pharmacological treatment of Korean children and adolescents; data from the Korea National Health and Nutrition Examination Survey IV (2007-2009). PLoS One 2012;7(12).

[10] Haney EM, Huffman LH, Bougatsos C, Freeman M, Fu R, Steiner RD, et al. Screening for lipid disorders in children and adolescents: systematic evidence review for the US preventive services task force. Portland, Oregon: Oregon Evidence-based Practice Center; 2007.

[11] Silva CAB. Doença Cardiovascular e seu início durante a infância. RPBS 2009;22(2):67–8.

[12] Turer CB, Brady ATM, Ferranti ASD. Obesity, hypertension, and dyslipidemia in childhood are key modifiable antecedents of adult cardiovascular disease. Circulation 2018;137(12):1256–9. https://doi.org/10.1161/CIRCULATIONAHA.118.032531.

[13] Lim S, Meigs JB. Ectopic fat and cardiometabolic and vascular risk. Int J Cardiol 2013;169:166–76. https://doi.org/10.1016/j.ijcard.2013.08.077.

[14] Pitangueira JCD, Silva L, Santana MLP, Silva MCM, Costa PRF, D'Almeida LV, et al. Metabolic syndrome and associated factors in children and adolescents of a Brazilian municipality. Nutr Hosp 2014;29(4):865e72.

[15] Araki M, Barros C, Santos E. Análise do perfil lipídico de crianças e adolescentes do estado de sergipe. Sci Plena 2010;6(12).

[16] Taylor BV, Oudit GY, Evans M. Homocysteine, vitamins, and coronary artery disease e comprehensive review of the literature. Can Fam Physician 2000;46:2236e45.

[17] Lohman T, Roche A, Martorell R. Anthropometric standardization reference manual. Human Kinetics Books; 1988.

[18] Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ 2007;85:660e7.

[19] Maffeis C, Banzato C, Talamini G. Obesity Study Group of the Italian Society of Pediatric Endocrinology and Diabetology. Waist-to-height ratio, a useful index to identify high metabolic risk in overweight children. J Pediatr 2008;152:207–13.

[20] Valdez R. A simple model-based index of abdominal adiposity. J Clin Epidemiol 1991;44(9):955–6.

[21] Fredman 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(2):308–17.

[22] Assis A, Monteiro M, Santana M, Santos N. Diagnóstico de saúde e nutrição da população de Mutuípe-Ba. Salvador: Editora UFBA; 2002.

[23] Monteiro RCA, Riether PTA, Burini RC. Efeito de um programa misto de intervenção nutricional e exercício físico sobre a composição corporal e os hábitos alimentares de mulheres obesas em climatério. Rev Nutr 2004;17:479e89.

[24] Costa PRF, Kinrac S, D'Almeida V, Assis AMO. Serum homocysteine and cysteine levels and change in lipid profile of children and adolescents over a 12-month follow-up period. Clin Nutr ESPEN 2017;21:13–9.

Please cite this article as: Costa PRdF et al., Anthropometric status and lipid profile among children and adolescents: Changes after 18-month follow-up, Clinical Nutrition ESPEN, https://doi.org/10.1016/j.clnesp.2019.10.004

[25] Labarthe D, Nichaman M, Harrist R, Grunbaum J, Dai S. Change in blood lipid components during adolescence differs importantly by sex and is not consistently related to change in body fat: project heartbeat! Can J Cardiol 1997;13(Suppl. B).

[26] Jolliffe CJ, Janssen I. Distribution of lipoproteins by age and gender in adolescents. Circulation 2006;114(10):1056e62.

[27] Twisk J. In: Applied longitudinal data analysis for epidemiology: a practical guide. Cambridge: Cambridge University Press; 2013.

[28] Cui J. QIC program and model selection in GEE analyses. STATA J 2007;7(2): 209—20.

[29] Bacopoulou F, Efthymiou V, Landis G, Rentoumis A, Chrousos GP. Waist circumference, waist-to-hip ratio and waist-to-height ratio reference percentiles for abdominal obesity among Greek adolescents. BMC Pediatr 2015;15(50).

[30] Mushtaq MU, Gull S, Abdullah HM, Shahid U, Shad MA, Akram J. Waist circumference, waist-hip ratio and waist-height ratio percentiles and central obesity among Pakistani children aged five to twelve years. BMC Pediatr 2011;11(105).

[31] Schröder H, Ribas L, Koebnick C, Funtikova A, Gomez SF, Fíto M, et al. Prevalence of abdominal obesity in Spanish children and adolescents. Do we need waist circumference measurements in pediatric practice? PLoS One 2014;9(1).

[32] Lozano P, Henrikson NB, Morrison CC, Dunn J, Nguyen M, Blasi P, et al. Lipid screening in childhood for detection of multifactorial dyslipidemia: a systematic evidence review for the U.S. Preventive services task force. Rockville (MD): Agency for Healthcare Research and Quality (US); 2016 Aug. Report No: 14-05204-EF-1.

[33] Furtado JM, Almeida SM, Mascarenhas P, Ferraz ME, Ferreira JC, Vilanova M, et al. Anthropometric features as predictors of atherogenic dyslipidemia and cardiovascular risk in a large population of school-aged children. PLoS One 2018;13(6).

[34] Pinto ICS, Arruda IKG, Diniz AS, Cavalcanti AMTS. Prevalência de excesso de peso e obesidade abdominal, segundo parâmetros antropométricos, e associação com maturação sexual em adolescentes escolares. Cad Saúde Pública 2010;26(9):1727—37.

[35] Tchernof A, Després JP. Pathophysiology of human visceral obesity: an update. Physiol Rev 2013;93(1):359—404.

[36] Mamalakis G, Kafatos A, Manios Y, Kalogeropoulos N, Adrikopoulos N. Abdominal vs buttock adipose fat: relationship with children's serum lipid levels. Eur J Clin Nutr 2002;56(11):1081—6.

[37] Oliveira CL, Mello MT, Cintra IP, Fisberg M. Obesidade e síndrome metabólica na infância e adolescência. Rev Nutr 2004;17(2):237—45.

[38] Tresaco B, Moreno LA, Ruiz JR, Ortega FB, Bueno G, González-Gross M, et al. Truncal and abdominal fat as determinants of high triglycerides and low HDL-cholesterol in adolescents. Obesity 2009;17(5):1086—91.

[39] Arruda Neta ACP, Farias Júnior JC, Martins PR, Ferreira FELL. Índice de conicidade como preditor de alterações no perfil lipídico em adolescentes de uma cidade do Nordeste do Brasil. Cad Saúde Pública 2017;33(3).

[40] Mascarenhas LPG, Leite N, Titski ACCK, Brito LMS, Boguszewski MCS. Variability of lipid and lipoprotein concentrations during puberty in Brazilian boys. J Pediatr Endocrinol 2015;28(1—2):125—31.

Please cite this article as: Costa PRdF et al., Anthropometric status and lipid profile among children and adolescents: Changes after 18-month follow-up, Clinical Nutrition ESPEN, https://doi.org/10.1016/j.clnesp.2019.10.004