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Effects of preterm birth and fetal growth retardation on life-course cardiovascular risk factors among schoolchildren from Colombia: The FUPRECOL study

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ABSTRACT

Background: Both fetal growth restriction and prematurity have been associated with cardiometabolic risk in youth and adults, however, data on their combined effects on cardiometabolic health in youth are scarce.
Aims: This study aimed at assessing the effects of birth weight and gestational age combined on life-course cardiovascular risk factors and obesity among schoolchildren from Colombia.
Study design: A cross-sectional study.
Subjects: Participants comprised 2510 Colombian schoolchildren (54.8% girls) aged 9–17.9 years.
Outcome measures: Four groups were created according to WHO criteria: those born at term with an appropriate birth weight (≥2500 g to ≤4000 g) for gestational age (term AGA); those born preterm (<37 to <42 completed weeks) with an appropriate birth weight for gestational age (preterm AGA); those born at term with low birth weight for gestational age (term SGA); and those born preterm with low birth weight for gestational age (preterm SGA). Anthropometric markers (body mass, height, waist circumference, and body mass index), blood pressure, lipids profile, fasting glucose, and pubertal stage were assessed. The prevalence of metabolic syndrome was determined by de Ferranti definition.
Results: There were differences between the 4 groups for calendar age ($p = 0.011$), body mass ($p = 0.001$), height ($p = 0.001$), and body mass index ($p = 0.027$). Overall, preterm SGA group had a greater risk for having elevated fasting glucose and metabolic syndrome (total sample and in boys) compared with term AGA group ($p < 0.05$). For other cardiovascular risk factors, no significant relationships were observed based on birth characteristics.
Conclusions: School-age children and adolescents with combined fetal growth restriction and prematurity exhibited an increased prevalence of glucose risk and metabolic syndrome.

1. Introduction

Previous large cohort studies have shown that birth weight (BW) and gestational age (GA) are independent risk factors of overweight/obesity, type 2 diabetes, and cardiovascular disease (CVD) [1,2]. Albeit the precise mechanisms for this association remain unclear, metabolic changes that could be related to alterations in body composition can be found already in childhood [3]. For instance, individuals with low BW present higher plasma inflammatory and metabolic biomarkers concentrations than would be expected from their degree of obesity [4,5]. For this reason, international organizations such as The World Health Organization (WHO) and United Nations Millennium Development Goals, included BW as one of the most important factors affecting child morbidity and mortality; e.g., approximately one third of neonatal deaths are attributable to it [6].

Epidemiological studies have reported a relationship between BW and CVD risk factors in adolescents and adults with a "U-shaped" or

Abbreviations: AGA, appropriate birth weight for gestational age; BMI, body mass index; BW, birth weight; CVD, cardiovascular disease; GA, gestational age; SES, socioeconomic status; SGA, low birth weight for gestational age; WHO, World Health Organization.

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"J-shaped" response curve, but showing greater risk factors clustering in individuals with low BW [1–3,7]. For example, infants with low BW have been reported to typically have poor muscle tissue and insulin resistance and glucose intolerance [8]. Regarding GA, scientific evidence indicates a dose-response relationship between shorter length of gestation and increasing levels of cardiovascular risk factors during adolescence [8]. These investigators also found that young adults who were born preterm had higher levels of cardiometabolic risk factors and were 2.5 to 4 times more likely to meet the criteria of metabolic syndrome than were their peers who were born at full term [9]. In contrast, some studies reported that preterm birth is not associated with greater cardiovascular risk in youth [10,11].

Both BW and GA are leading CVD risk factors among Hispanic/Latino adults, raising concerns about whether an increased risk of these conditions are also manifested at younger ages [1,8–10]. Few studies have been analyzed the combined effect of both BW and GA on cardiometabolic risk factors among young population, especially of Hispanic/Latino ethnicity. The study of Juanola et al. [12] did observe in young Finns increased blood pressure levels among those individuals born prematurely, who also had fetal growth restriction. In addition, another study found that preterm birth, but not growth retardation at term, was associated with higher blood pressure and a less favorable fat distribution [13]. For that reason, describing the magnitude of these risk factors in youth is important for prioritizing prevention and public health efforts [14]. Thus, this study aimed at assessing the effects of BW and GA combined on life-course cardiovascular risk factors and obesity among schoolchildren from Bogota, Colombia.

2. Methods

2.1. Study design

The FUPRECOL Study (in Spanish -*Asociación de la fuerza prensil con manifestaciones de riesgo cardiovascular tempranas en niños y adolescentes colombianos*-) is a cross-sectional study that seeks to establish the general prevalence of CVD risk factors (anthropometric, adiposity, metabolic and genetic markers) in the study population (children and adolescents aged 9 to 17.9 years living in Bogota, Colombia) [15,16]. The intent of the study was to examine the relationships between physical fitness levels and CVD risk factors during the 2014–2015 school year.

2.2. Study population

The FUPRECOL study was conducted from 2014 to 2015 in a convenience sample of volunteers and grouped by sex and age with one-year increments (a total of nine groups). In total, 8000 school children from 27 official schools aged 9.0–17.0 years, with valid data for gender and body mass index (BMI) were included in a primary study. In this paper, we analyzed a secondary cross-sectional study data set for the main set consisting of the neonatal, anthropometric and cardiometabolic parameters ($n = 2510$) assessed in the Colombian schoolchildren (54.8% girls). All schoolchildren were of low-middle socioeconomic status (SES, 1–3 in a scale of 1–6 defined by the Colombian government) and enrolled in public elementary and high schools (grades 5 through 11) in the capital district of Bogota, Cundinamarca Department in the Andean region. Exclusion factors included clinical diagnosis of cardiovascular disease, diabetes mellitus 1 and 2, pregnancy, use of alcohol or drugs, macrosomia (defined as weight at birth ≥ 4000 g), and not having lived in Bogota for at least one school year. None of the study participants were on any medical drugs treatment. Exclusion from the study was made effective a posteriori, without the students being aware of their exclusion, to avoid any undesirable situations.

2.3. Neonatal outcomes

Families provided the BW by presenting the vaccine chart and/or live birth certificate, all official documents provided by the maternity on the day of birth. At the initial interview, the parents/guardians were asked about their official BW documents. The sample was further limited to those whose BW was either registered in the birth certificate, or the mother affirmed (during data collection) to accurately recall the BW and she provided a valid value. The BW was classified as follows: low BW (<2500 g) and normal BW (≥2500 to ≤4000 g), on the basis of the WHO [17] definition. Regarding GA, information about the onset of the delivery was retrieved from the medical records of the respective obstetric center. The duration of gestation was categorized as preterm (<37 completed weeks, 154–258 days) and term GA (37 to <42 completed weeks, 259–293 days), according to WHO [17] definition.

2.4. Anthropometric and adiposity variables

Variables were collected at the same time in the morning, between 7:00 and 10:00 a.m., following an overnight fast. Body weight and height were measured using standard procedures with electronic scales (Tanita® BC544, Tokyo, Japan) and mechanical stadiometer platform (Seca® 274, Hamburg, Germany), respectively. Body mass index (BMI) was calculated as the body mass (weight) in kilograms divided by the square of height in meters. Weight status (i.e., underweight, normal weight, or overweight/obese) was defined according to the International Obesity Task Force (IOTF) age and sex-specific thresholds for BMI [18]. Waist circumference (WC) was measured at the midpoint between the last rib and the iliac crest using a tape measure (Ohaus® 8004-MA, Parsippany, NJ, USA). In all the measures, high levels of test-retest reliability [body weight (intraclass correlation, ICC = 0.983), height (ICC = 0.973), BMI (ICC 0.897), and WC (ICC = 0.967)] were found.

We used a classical bipolar technique to estimate body fat (%) using a BIA-TANITA® Model BF689 (Tanita, Tokyo, Japan; TEM = 0.639) according to the manufacturer's instructions. The mean of two readings was used, taken in the morning under controlled temperature - humidity conditions, after urination and a 15-minute rest with the child shoeless and fasted. A detailed description of the BIA technique can be found elsewhere [19]. The corresponding intra-observer technical error (reliability) of the measurements was 0.95%.

2.5. Resting blood pressure

An electronic oscillometric device was used to determined resting blood pressure (Riester Ri-Champion model, Jungingen, Germany) twice after being seated in a quiet room for 10 min with their back supported by two researchers and their feet on the ground. Two blood pressure readings were taken with a 10 min interval of quiet rest between measurements. Before blood pressure session monitoring, the accuracy of the device was tested against a standard mercury sphygmomanometer in a random sub-sample ($n = 25$) to ensure that there was no consistent difference of >10 mm Hg in measured blood pressure and inter-observer variability was $R = 0.96$. Mean systolic blood pressure was defined as ideal (<90th centile *and* mean diastolic blood pressure < 90th centile), or non-ideal (systolic blood pressure ≥ 90th centile *or* diastolic blood pressure ≥ 90th centile). All centile-based threshold limits were sex- and age-specific and selected on the basis of the International Diabetes Federation [20] definition of metabolic syndrome.

2.6. Biochemical assessments

Blood samples were collected between 6:00 and 8:00 a.m. after at least 12 h fasting by two experienced paediatric phlebotomists. Blood

samples were obtained from an antecubital vein, and analyses were subsequently completed within 1 day from collection. The levels of triglycerides (TG), total cholesterol, cholesterol linked to high-density lipoproteins (HDL-c) and glucose were measured using colorimetric enzymatic methods, employing a Cardiocheck analyzer. The fraction of cholesterol linked to low-density lipoproteins (LDL-c) was calculated using the Friedewald formula [21]. Inter-assay reproducibility (coefficient of variation), determined from 80 replicate analyses of 8 plasma pools over 15 days, revealed a maximum inter-assay coefficient of variation of 3.3% and a maximum intra-assay coefficient of variation of 8.3%.

2.7. Cardiometabolic risk assessment and diagnosis of metabolic syndrome

The prevalence of metabolic syndrome and its components (unhealthy and healthy categories) were evaluated according to de Ferranti et al. [22]. The diagnosis of metabolic syndrome required meeting at least three of the following five criteria: TG ≥ 100 mg/dL; HDL-c < 50 mg/dL (<45 mg/dL for boys aged 9 to 19 years); fasting glycemia ≥ 110 mg/dL; WC > 75th percentile for age and gender; and systolic blood pressure > 90th percentile for age, gender and height.

2.8. Sexual maturation

Maturation status was assessed by the classification described by Tanner (self-reported pubertal status), which is based on the extent of hair covering of the pubertal regions (five stages: I—V) [23]. Each participant entered an isolated room, where using a set of images exemplifying the various stages of sexual maturation, they categorized the development of their own genitalia (for boys), breasts (for girls), armpits (for boys) and pubic hair (for both genders). The reproducibility of our data reached 78%. All data were recorded on paper by FUPRECOL evaluators.

2.9. Ethics statement

The study protocol was explained verbally to the participants and their parents/guardians before they gave their written consent. Participation in the study was fully voluntary and anonymous, with no explicit incentives provided for participation. The Review Committee for Research on Human Subjects at the University of Rosario (code no. CEI-ABN026-000262) approved all study procedures. The protocol was in accordance with the latest revision of the Declaration of Helsinki and current Colombian laws governing clinical research on human subjects (Resolution 008430/1993 Ministry of Health).

2.10. Statistical analysis

The normality of the distribution of the variables was assessed by use of the Shapiro-Wilk test. The results are presented as the mean (standard deviation) or relative frequency as a percentage. Differences between neonatal groups, anthropometric characteristics, cardiovascular risk factor and number of metabolic syndrome components were assessed by analysis of variance (ANOVA). Four groups were created: i) term AGA: those born at term with an appropriate BW for GA; ii) preterm AGA: those born preterm with an appropriate BW for GA; iii) term SGA: those born at term with low BW for GA (SGA); and iv) preterm SGA: those born preterm with low BW for GA. Multiple logistic regression was used to determine the independence of the influence for the variables associated with each group (term AGA, preterm AGA, term SGA, and preterm SGA), identified by using bivariate analysis adjusted for gender, age, pubertal stage, and weight status in all participants. All the analyses were carried out using the IBM SPSS 21 (SPSS, Inc., Chicago, Illinois, USA). The level of statistical significance was established as $p < 0.05$.

3. Results

Table 1 shows the demographic descriptive statistics of the sample. The final sample had a mean age of 13.2 (2.2) [range 11–14] years and contained slightly more females (54.8%). There were significant differences between groups for calendar age, body mass, height, and BMI. Pairwise comparisons showed lower values of height in preterm SGA group compared with the other groups. Also, preterm SGA group reported lower values of age and body mass compared with term AGA and preterm AGA groups. In other parameters, no significant differences were observed based on birth characteristics.

Table 2 shows the multiple logistic regressions of the variables associated with the birth characteristics using bivariate analysis adjusted for gender, age, pubertal stage, and weight status. In the whole sample, the preterm SGA group showed higher likelihood (OR) to have unhealthy fasting glucose levels (OR = 1.84, CI 95% 1.05 to 3.23; $p < 0.001$) and metabolic syndrome (OR = 1.58, CI 95% 1.04 to 2.41; $p < 0.001$) compared to the reference group (preterm IGA). In boys, preterm SGA (OR = 2.13, CI 95% 1.13 to 4.04; $p < 0.001$) showed higher odds of having metabolic syndrome compared to the reference group.

4. Discussion

Having reached term-born status seems to be a protecting factor from metabolic syndrome in school-age children and adolescents. In the current study, school-age children and adolescents with combined fetal growth restriction and prematurity did exhibit an increased prevalence of glucose risk and metabolic syndrome. Therefore, our findings suggest that premature youths, preterm SGA, may require additional long-term follow up of their cardiovascular health.

In a recent cross-sectional study conducted in a total of 10,692 Colombian children the prevalence of low BW was 8.7%. In the current study the prevalence of was comparable at 10.1%. Our data confirms what has been reported by the Colombian National Department of Statistics (DANE) and by non-governmental organizations in the country –"*Asi vamos en salud*", *in Spanish*–, which estimated a national low BW prevalence between 8 and 9% [24]. In our study, youth who belong to the term AGA group showed significant differences for body mass and height compared to the unhealthy group. Previous evidence supports our findings, which has reported that infants with low BW had poor muscle tissue in prepubertal children [25]. However, other factors must also be taken into account, since in the current study the term AGA group displayed higher age and pubertal stage than preterm SGA group. Moreover, there were other important factors which were impossible to measure in the present study, such as; data about complete prenatal care, which appears to be of great importance to the decreased (low) BW, and avoidance of related future complications [26].

Regarding individual components of metabolic syndrome, evidence shows controversial results about it relationship with BW and GA individually. Our study shows that to be preterm or with low BW is not related with any individual cardiovascular risk factor compared to term born youths. These findings corroborate previous findings in other countries [9,27]. For example, prematurity did not increase obesity risk in adolescents ($n = 134$) from Brazil [10]. However, despite the relationship being non-significant for cardiovascular risk factors and neonatal outcomes, all our values tended to be less healthy in the three groups compared to term born youths.

Assessing both neonatal characteristics, our study shows that the preterm SGA group had higher risk for having higher fasting glucose compared with term AGA group. This is probably associated with reduced insulin sensitivity in preterm SGA youths [10,11]. Our results, however, are not in accordance with those of Willemsen et al. [28] which analyzed 479 prepubertal short children born SGA. This study showed that those born preterm had a higher systolic and diastolic blood pressure, lower percent body fat and higher insulin secretion and disposition index than term SGA children, but no differences in

Table 1
Mean, standard deviation and relative frequency [%] according to birth weight and gestational age groups by anthropometrics, cardiovascular risk factor and number of metabolic syndrome components.

Variables	Term AGA (1)	Term SGA (2)	Preterm AGA (3)	Preterm SGA (4)	All participants	P trend
Anthropometric characteristics						
n [%]	1158 [46.1]	260 [10.3]	843 [33.5]	249 [10.1]	2510 [100]	
Boys	516 [44.6]	123 [47.3]	394 [46.7]	101 [40.6]	1134 [45.2]	0.305
Girls	642 [55.4]	137 [52.7]	449 [53.3]	148 [59.4]	1376 [54.8]	
Age (years)	13.3 (2.2)	13.1 (2.8)	13.2 (2.2)	12.8 (2.3)[a,c]	13.2 (2.2)	0.011
Body mass (kg)	47.3 (11.4)	45.9 (44.4)	47.1 (11.7)	44.3 (11.8)[a,c]	46.8 (2.2)	0.001
Height (cm)	153.4 (11.6)	152.5 (150.9)	153.1 (12.2)	150.0 (11.9)[a,b,c]	152.8 (11.6)	0.001
Body mass index (kg/m^2)	19.8 (3.0)	19.4 (19.1)	19.9 (3.2)	19.4 (3.2)	19.7 (3.1)	0.027
Waist circumference (cm)	64.8 (7.5)	64.0 (63.0)	64.7 (7.5)	63.5 (8.0)	64.6 (7.6)	0.055
Weight status n [%]						
Underweight	176 [15.2]	46 [17.7]	121 [14.4]	46 [18.5]	389 [15.5]	0.466
Normal weight	712 [61.5]	161 [61.9]	507 [60.1]	143 [57.4]	1523 [60.7]	
Overweight	215 [18.6]	40 [15.4]	161 [19.1]	43 [17.3]	459 [18.3]	
Obese	55 [4.7]	13 [5.0]	54 [6.4]	17 [6.8]	139 [5.5]	
Pubertal stage n (%)						
I	68 [5.9]	16 [6.2]	66 [7.8]	21 [8.4]	171 [6.8]	0.066
II	238 [20.6]	54 [20.8]	179 [21.2]	71 [28.5]	542 [21.6]	
III	363 [31.3]	85 [32.7]	275 [32.6]	79 [31.7]	802 [32.0]	
IV	410 [35.4]	91 [35.0]	284 [33.7]	68 [27.3]	853 [34.0]	
V	79 [6.8]	14 [5.4]	39 [4.6]	10 [4.0]	142 [5.7]	
Cardiovascular risk factors						
Systolic blood pressure (mm Hg)	111.4 (12.9)	110.3 (13.4)	112.4 (13.4)	111.5 (14.1)	111.6 (13.3)	0.100
Diastolic blood pressure (mm Hg)	68.6 (8.9)	67.3 (8.9)	68.4 (9.0)	68.2 (8.8)	68.4 (13.3)	0.233
Total cholesterol (mg/dl)	141.5 (25.2)	140.4 (26.0)	140.7 (25.4)	143.3 (25.2)	141.3 (8.9)	0.483
HDL cholesterol (mg/dl)	46.6 (11.6)	46.9 (12.6)	46.6 (12.0)	47.2 (11.8)	46.7 (11.9)	0.874
LDL cholesterol (mg/dl)	81.0 (25.5)	81.5 (29.1)	79.1 (24.8)	81.8 (25.0)	80.5 (25.6)	0.269
Triglycerides (mg/dl)	89.6 (46.2)	89.1 (39.7)	88.7 (38.6)	90.8 (39.0)	89.4 (42.4)	0.917
Fasting glucose (mg/dl)	82.0 (15.1)	82.9 (16.8)	82.3 (15.5)	82.8 (16.7)	82.3 (15.6)	0.779
Number of Metabolic syndrome criteria n [%][d]						
No criterion	234 [20.2]	47 [18.1]	194 [23.0]	53 [21.3]	528 [21]	0.086
1 criterion	528 [45.6]	122 [46.9]	332 [39.4]	101 [40.6]	1083 [43.1]	
2 criteria	294 [25.4]	71 [27.3]	233 [27.6]	62 [24.9]	660 [26.3]	
3 or more criteria	102 [8.8]	20 [7.7]	84 [10.0]	33 [13.3]	239 [9.5]	

Bonferroni-adjusted pairwise significant differences.
AGA, appropriate birth weight for gestational age; SGA, low birth weight for gestational age.
[a] 1 vs. 4, $p < 0.001$.
[b] 2 vs. 4, $p < 0.001$.
[c] 3 vs. 4, $p < 0.001$.
[d] Number of metabolic syndrome (MS) were defined according criteria de Ferranti et al. [27].

fasting glucose. The Cardiovascular Risk in Young Finns Study found in 1756 adults that preterm AGA persons did not have elevated cardiovascular risk factors when compared with those born at term [13]. Finally, young adults who were born term SGA did not exhibit increased prevalence of any of cardiovascular risk factors compared to those who term born [13]. The differences between the present study and earlier studies may be caused by cut-off values used to defined health risk status in each parameter.

Birth weight reflects the pattern of intrauterine growth, and being born SGA might have long-term impacts on chronic disease in youths and adulthood [1–4,12], however the mechanisms of such "metabolic imprinting" are not yet been understood [13]. The results of the first survey of the CASPIAN (Childhood & Adolescence Surveillance and Prevention of Adult Non-communicable disease) study showed that girls who are born small for GA are at a higher risk for metabolic syndrome [29]. Contrastingly, the NEOLONG study reported neither low BW at birth nor short stature at follow-up, could be associated with parameters that indicate an increased risk for the metabolic syndrome during childhood [30]. In our study, in boys and in the whole of sample, being preterm and SGA increased the risk of having metabolic syndrome. Currently no universally accepted definition of metabolic syndrome exists for children and adolescents, therefore discrepancies between results and its relationship with neonatal outcomes could be due to this lack of agreement. In addition, the gender differences that we found in terms of the association between BW and the risk of developing metabolic syndrome in childhood should be examined in longitudinal studies.

This study has several strengths. To our knowledge, our study is the first to evaluate the relationship between BW and GA with cardiovascular risk factors in schoolchildren from Colombia. Also, few studies have analyzed the combined effect of BW and GA on cardiometabolic risk factors in any youth population. However, several limitations should also be mentioned. First, this study did not include nutritional data from infancy, because, although observation studies have suggested that programming extends throughout the first years of life, with breastfeeding representing a protective effect, their results are controversial [13,30]. Moreover, other factors were not studied such as prenatal care, one of the most important tools available to health care providers to detect time-sensitive, modifiable obstetric risk factors (infections, micronutrients deficiencies, metabolic, and placental diseases) that may impact on optimal fetal development, as well as final BW. The possibility of confounding by socioeconomic status has also to be considered, but no associations were found on socioeconomic status between groups, due to all participants belonging to low-middle socioeconomic status.

5. Conclusions

Our findings suggest that being born premature is not in itself an exposure sufficient enough to impact upon youth cardiometabolic health,

Table 2
Multiple logistic regressions of the variables associated with to birth weight and gestational age groups using bivariate analysis adjusted age, pubertal stage, and weight status by gender.

Variables	Boys			Girls			All participants		
	OR	CI	95%	OR	CI	95%	OR	CI	95%
Overweight + obesity									
Preterm AGA	0.92	0.53	1.60	0.82	0.54	1.25	0.84	0.61	1.17
Term SGA	1.35	0.96	1.90	1.04	0.80	1.36	1.13	0.92	1.38
Preterm SGA	1.41	0.83	2.41	0.86	0.57	1.28	1.04	0.76	1.44
High waist circumference									
Preterm AGA	0.62	0.18	2.12	1.12	0.42	3.02	0.87	0.40	1.87
Term SGA	1.05	0.54	2.05	1.31	0.69	2.46	1.18	0.75	1.87
Preterm SGA	1.85	0.76	4.49	0.61	0.18	2.08	1.14	0.56	2.31
High systolic blood pressure									
Preterm AGA	0.82	0.45	1.48	0.99	0.56	1.75	0.90	0.60	1.36
Term SGA	1.32	0.92	1.87	1.28	0.90	1.83	1.31	1.02	1.68
Preterm SGA	1.45	0.84	2.51	1.37	0.83	2.27	1.39	0.96	2.02
High diastolic blood pressure									
Preterm AGA	1.15	0.60	2.20	0.60	0.31	1.15	0.80	0.51	1.27
Term SGA	1.32	0.86	2.02	0.84	0.57	1.22	1.02	0.77	1.35
Preterm SGA	1.32	0.67	2.57	0.89	0.51	1.55	1.04	0.68	1.60
High total cholesterol									
Preterm AGA	1.29	0.72	2.31	0.99	0.60	1.62	1.09	0.75	1.58
Term SGA	0.91	0.59	1.40	0.98	0.71	1.35	0.94	0.73	1.22
Preterm SGA	1.41	0.76	2.59	0.85	0.52	1.40	1.04	0.71	1.53
Low HDL cholesterol									
Preterm AGA	0.92	0.62	1.37	0.82	0.57	1.19	0.87	0.66	1.13
Term SGA	1.21	0.93	1.58	0.93	0.73	1.18	1.05	0.88	1.25
Preterm SGA	1.30	0.85	1.99	1.24	0.87	1.78	1.27	0.97	1.67
High LDL cholesterol									
Preterm AGA	1.60	0.93	2.74	0.57	0.29	1.13	1.01	0.67	1.53
Term SGA	0.90	0.59	1.37	0.73	0.49	1.08	0.80	0.60	1.07
Preterm SGA	1.14	0.60	2.18	1.00	0.58	1.73	1.06	0.70	1.61
High triglycerides									
Preterm AGA	1.09	0.67	1.77	1.32	0.90	1.94	1.20	0.89	1.61
Term SGA	1.07	0.77	1.48	1.02	0.78	1.32	1.02	0.84	1.25
Preterm SGA	1.41	0.86	2.31	1.03	0.70	1.52	1.18	0.87	1.60
High fasting glucose									
Preterm AGA	0.92	0.53	1.60	0.82	0.54	1.25	1.35	0.73	2.48
Term SGA	1.35	0.96	1.90	1.04	0.80	1.36	1.02	0.66	1.60
Preterm SGA	1.41	0.83	2.41	0.86	0.57	1.28	**1.84**	**1.05**	**3.23**
Metabolic syndrome									
Preterm AGA	0.52	0.20	1.34	1.13	0.62	2.05	0.86	0.52	1.42
Term SGA	1.31	0.82	2.08	1.05	0.70	1.57	1.15	0.85	1.55
Preterm SGA	**2.13**	**1.13**	**4.04**	1.27	0.73	2.22	**1.58**	**1.04**	**2.41**

Reference group: term and appropriate birth weight for gestational age.
AGA, appropriate birth weight for gestational age; SGA, low birth weight for gestational age. Bold text indicates $P < 0.05$.

but that individuals also need to be born with SGA. If this is the case then these youths should require additional long-term follow-up healthcare. We recommend there is a need for future prospective studies initiated in the prenatal period. These will be important to clarify the complex mechanism of adaptation to fetal growth restrictions or excesses, as the most effective way to ensure a healthy metabolic development throughout childhood.

Competing interests

The authors declare that they have no competing interests.

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References

[1] R. Kelishadi, A.A. Haghdoost, F. Jamshidi, M. Aliramezany, M. Moosazadeh, Low birthweight or rapid catch-up growth: which is more associated with cardiovascular disease and its risk factors in later life? A systematic review and cryptanalysis, Paediatr. Int. Child. Health 35 (2015) 110–123.
[2] J.W. Rich-Edwards, M.J. Stampfer, J.E. Manson, B. Rosner, S.E. Hankinson, G.A. Colditz, W.C. Willett, C.H. Hennekens, Birth weight and risk of cardiovascular disease in a cohort of women followed up since 1976, BMJ 315 (1997) 396–400.
[3] F.R. Jornayvaz, P. Vollenweider, M. Bochud, V. Mooser, G. Waeber, P. Marques-Vidal, Low birth weight leads to obesity, diabetes and increased leptin levels in adults: the CoLaus study, Cardiovasc. Diabetol. 15 (2016) 73, http://dx.doi.org/10.1186/s12933-016-0389-2.
[4] M.G. Musa, J. Kagura, P.T. Pisa, S.A. Norris, Relationship between early growth and CVD risk factors in adolescents, J. Dev. Orig. Health. Dis. 7 (2016) 132–143.
[5] U. Lausten-Thomsen, M. Olsen, G. Greisen, K. Schmiegelow, Inflammatory markers in umbilical cord blood from small-for-gestational-age newborns, Fetal. Pediatr. Pathol. 33 (2014) 114–118.
[6] World Health Organization WHO, Guidelines on optimal feeding of low birthweight infants in low-and middle-income countries, World Health Organization, Geneva, 2011.
[7] P.D. Gluckman, M.A. Hanson, C. Cooper, K.L. Thornburg, Effect of in utero and early-life conditions on adult health and disease, N. Engl. J. Med. 359 (2008) 61–73.
[8] M. Sipola-Leppänen, M. Vääräsmäki, M. Tikanmäki, P. Hovi, S. Miettola, A. Ruokonen, A. Pouta, M.R. Järvelin, E. Kajantie, Cardiovascular risk factors in adolescents born preterm, Pediatrics 134 (2014) 1072–1081.
[9] M. Sipola-Leppänen, M. Vääräsmäki, M. Tikanmäki, H.M. Matinolli, S. Miettola, P. Hovi, K. Wehkalampi, A. Ruokonen, J. Sundvall, A. Pouta, J.G. Eriksson, M.R. Järvelin, E. Kajantie, Cardiometabolic risk factors in young adults who were born preterm, Am. J. Epidemiol. 181 (2015) 861–873.
[10] P.J. Alves, E. Araujo Júnior, A.C. Henriques, F.H. Carvalho, Preterm at birth is not associated with greater cardiovascular risk in adolescence, J. Matern. Fetal. Neonatal. Med. 29 (2016) 3351–3357.
[11] R.H. Willemsen, S.W. de Kort, D.C. van der Kaay, A.C. Hokken-Koelega, Independent effects of prematurity on metabolic and cardiovascular risk factors in short small-for-gestational-age children, J. Clin. Endocrinol. Metab. 93 (2008) 452–458.
[12] M. Juonala, M.M. Cheung, M.A. Sabin, D. Burgner, M.R. Skilton, M. Kähönen, N. Hutri-Kähönen, T. Lehtimäki, A. Jula, T. Laitinen, E. Jokinen, L. Taittonen, P. Tossavainen, J.S. Viikari, C.G. Magnussen, O.T. Raitakari, Effect of birth weight on life-course blood pressure levels among children born premature: the cardiovascular risk in young Finns study, J. Hypertens. 33 (2015) 1542–1548.
[13] K.A. Evensen, S. Steinshamn, A.E. Tjønna, T. Stølen, M.A. Høydal, U. Wisløff, A.M. Brubakk, T. Vik, Effects of preterm birth and fetal growth retardation on cardiovascular risk factors in young adulthood, Early Hum. Dev. 85 (2009) 239–245.
[14] The UN Millennium Development Goals, http://www.un.org/millenniumgoals/childhealth, 2015 (Accessed 20.06.2016).
[15] R. Ramírez-Vélez, D. Rodrigues-Bezerra, J.E. Correa-Bautista, M. Izquierdo, F. Lobelo, Reliability of health-related physical fitness tests among Colombian children and adolescents: the FUPRECOL study, PLoS One 10 (2015) (e0140875).
[16] R. Ramírez-Vélez, A. Anzola, J. Martinez-Torres, A. Vivas, A. Tordecilla-Sanders, D. Prieto-Benavides, M. Izquierdo, J.E. Correa-Bautista, A. Garcia-Hermoso, Metabolic syndrome and associated factors in a population-based sample of school children in Colombia: the FUPRECOL study, Metab. Syndr. Relat. Disord. 14 (2016) 455–462.
[17] World Health Organization (WHO), Expert Group on Prematurity: Final Report. (Technical Report series 27), Geneva, 1950.
[18] T.J. Cole, M.C. Bellizzi, K.M. Flegal, W.H. Dietz, Establishing a standard definition for child overweight and obesity worldwide: international survey, BMJ 320 (2000) 1240–1243.
[19] R. Ramírez-Vélez, J.E. Correa-Bautista, J. Martínez-Torres, K. González-Ruíz, E. González-Jiménez, J. Schmidt-RioValle, A. Garcia-Hermoso, Performance of two bioelectrical impedance analyses in the diagnosis of overweight and obesity in children and adolescents: the FUPRECOL study, Nutrients 8 (2016) 575.
[20] P. Zimmet, K.G.M.M. Alberti, F. Kaufman, N. Tajima, M. Silink, S. Arslanian, et al., The metabolic syndrome in children and adolescents – an IDF consensus report, Pediatr. Diabetes 8 (2007) 299–306.
[21] W.T. Friedewald, R.I. Levy, D.S. Fredrickson, Estimation of the concentration of low-density lipoprotein cholesterol in serum, without use of the preparative ultracentrifuge, Clin. Chem. 18 (1972) 499–502.
[22] S.D. de Ferranti, K. Gauvreau, D.S. Ludwig, E.J. Neufeld, J.W. Newburger, N. Rifai, Prevalence of the metabolic syndrome in American adolescents: findings from the Third National Health and Nutrition Examination Survey, Circulation 110 (2004) 2494–2497.
[23] J.M. Tanner, R.H. Whitehouse, Clinical longitudinal standards for height, weight, height velocity, weight velocity, and stages of puberty, Arch. Dis. Child. 51 (1976) 170–179.

[24] DANE, Estadísticas Vitales, Departamento Administrativo Nacional de Estadística, http://www.dane.gov.co/index.php/esp/poblacion-y-registros-vitales/nacimientos-y-defunciones/nacimientos-y-defunciones/118-demograficas/estadisticas-vitales/2882-nacimientos-2009-preliminar, 2014 (accessed 30.05.2016).
[25] A.W. van Deutekom, M.J. Chinapaw, T.G. Vrijkotte, R.J. Gemke, The association of birth weight and infant growth with physical fitness at 8-9 years of age – the ABCD study, Int. J. Obes. 39 (2015) 593–600.
[26] Á.M. Pinzón-Rondón, V. Gutiérrez-Pinzon, H. Madriñan-Navia, J. Amin, P. Aguilera-Otalvaro, A. Hoyos-Martínez, Low birth weight and prenatal care in Colombia: a cross-sectional study, BMC Pregnancy Childbirth 15 (2015) 118.
[27] M.K. Kwok, S.L. Au Yeung, G.M. Leung, C.M. Schooling, Birth weight and adult cardiovascular risk factors using multiple birth status as an instrumental variable in the 1958 British Birth Cohort, Prev. Med. 84 (2016) 69–75.
[28] R.H. Willemsen, S.W. de Kort, D.C. van der Kaay, A.C. Hokken-Koelega, Independent effects of prematurity on metabolic and cardiovascular risk factors in short small-for-gestational-age children, J. Clin. Endocrinol. Metab. 93 (2008) 452–458.
[29] R. Kelishadi, M.M. Gouya, K. Adeli, G. Ardalan, R. Gheiratmand, R. Majdzadeh, M.S. Mahmoud-Arabi, A. Delavari, M.M. Riazi, H. Barekati, M. Motaghian, K. Shariatinejad, R. Heshmat, CASPIAN Study Group, Factors associated with the metabolic syndrome in a national sample of youths: CASPIAN study, Nutr. Metab. Cardiovasc. Dis. 18 (2008) 461–470.
[30] M.B. Ranke, R. Schweizer, S.M. Rodemann, A. Bevot, D.D. Martin, R. Goelz, H.A. Wollmann, I. Krägeloh-Mann, G. Binder, Schoolchildren born VLBW or VLGA show height-related changes in body composition and muscle function but no evidence of metabolic syndrome risk factors. Results from the NEOLONG study, J. Pediatr. Endocrinol. Metab. 29 (2016) 163–172.