Nutrition, Metabolism & Cardiovascular Diseases (2019) **29**, 159–169

Available online at www.sciencedirect.com

Nutrition, Metabolism & Cardiovascular Diseases

journal homepage: www.elsevier.com/locate/nmcd

Lifestyle, anthropometric, socio-demographic and perinatal correlates of early adolescence hypertension: The Healthy Growth Study

Y. Manios [a,*], K. Karatzi [a], G. Moschonis [b], G. Ioannou [a], O. Androutsos [a], C. Lionis [c], G. Chrousos [d]

[a] *Department of Nutrition and Dietetics, School of Health Science & Education, Harokopio University of Athens, Greece*
[b] *Department of Rehabilitation, Nutrition and Sport, College of Science, Health and Engineering, La Trobe University, Bundoora, VIC 3086, Melbourne, Australia*
[c] *Clinic of Social and Family Medicine, School of Medicine, University of Crete, Heraklion, Crete, Greece*
[d] *First Department of Pediatrics, National and Kapodistrian University of Athens Medical School, "Aghia Sophia" Children's Hospital, Athens, Greece*

Received 4 April 2018; received in revised form 12 October 2018; accepted 15 October 2018
Handling Editor: A. Siani
Available online 25 October 2018

KEYWORDS
Childhood hypertension;
Lifestyle;
Perinatal;
Socio-demographic

Abstract *Background and aims:* Various lifestyle, anthropometric, socio-demographic and perinatal characteristics have been separately associated with elevated blood pressure in children and adolescents. The aim of this study was to simultaneously evaluate all potential risk factors and to identify the most dominant correlates of early adolescence hypertension in a large group of school children 9–13 years old.
Methods and results: A cross-sectional study with 1444 schoolchildren 9–13 years old, having full data on lifestyle, anthropometric, socio-demographic and perinatal indices, as well as blood pressure measurements. Early adolescents born large for their gestational age (LGA) (OR, 95% C.I. 0.49 (0.25–0.97)), those with higher levels of moderate to vigorous physical activity (MVPA) (OR, 95% C.I. 0.71 (0.53–0.96)) and those of a higher socioeconomic status (SES) (OR, 95% C.I. 0.51 (0.33–0.79)), had lower risk of hypertension, compared with their counterparts with appropriate birth weight, low levels of PA and with low SES respectively, independently of the variables used in the multivariate model. On the other hand, overweight and obese early adolescents (OR, 95% C.I. 2.61 (1.88–3.62)), those with central obesity (OR, 95% C.I. 1.75 (1.12–2.73)) and those having a hypertensive father (OR, 95% C.I. 1.93 (1.20–3.12)) had higher risk of hypertension compared with normal weight early adolescents and those without a family history of hypertension.
Conclusions: Among the parameters examined, early adolescence abnormal body weight and central obesity, low PA, non LGA, low SES family and family history of hypertension were found to be independently associated with higher risk of hypertension. The identified correlates of early adolescence hypertension can be used by public health initiatives for early detection and management of this major public health problem, prioritizing early adolescents and families at the highest possible risk for hypertension.

* Corresponding author. Harokopio University of Athens, Department of Nutrition and Dietetics, 70, El. Venizelou Ave, Kallithea, 17671, Athens, Greece. Fax: +30 210 9514759.
E-mail address: manios@hua.gr (Y. Manios).

https://doi.org/10.1016/j.numecd.2018.10.007

Introduction

Hypertension in childhood and adolescence is a constantly increasing health problem in the last decades. Prevalence of pre-hypertension and hypertension is reported to be around 20% in the US, 16.4% in Central Europe, and considerably higher in southern Europe, reaching 23% in Greece [1–3]. Hypertension in children and adolescents usually track into adulthood and hypertensive children have a high probability to become hypertensive adults with high cardiovascular risk [4]. Being one of the major risk factors for cardiovascular disease (CVD) in adults, it may also contribute to the initiation of vascular damage early in life [4]. Also, childhood hypertension is a risk factor for serious heart problems like left ventricular hypertrophy and congestive heart failure, which increases the risk of cardiovascular morbidity and mortality [5].

The origin of childhood and adolescence hypertension is multi-factorial, with various lifestyle, parental anthropometric, socio-demographic and perinatal indices being separately described as possible risk factors. Mother's weight gain and hypertension during pregnancy [6,7], male sex [8], family history of hypertension [9], socioeconomic status [10], obesity [11], low physical activity [12], unhealthy diet [13] and parental smoking [14] are the major risk factors separately reported to be associated with childhood hypertension in previous studies. On the other hand, there are several perinatal, sociodemographic and lifestyle parameters (i.e nationality, family status, type of delivery, breastfeeding) that have been either poorly or not yet investigated in relation to childhood and adolescence hypertension. Also, there is a significant number of already identified risk factors which are interrelated (i.e. excess calorie intake, low physical activity and excess body weight), making it difficult to identify the most important factors leading to childhood and adolescence hypertension.

To better understand the etiology of this health problem and, most importantly, to design future prevention programs in order to prevent or tackle childhood and adolescence hypertension prioritizing the most vulnerable population groups, it is essential to identify the most dominant risk factors, having an independent association with hypertension. The aim of the current study was to simultaneously investigate the associations of a significant number of lifestyle, anthropometric, socio-demographic and perinatal characteristics with hypertension in childhood and adolescence and to point out the most dominant correlates of hypertension in a large group of children 9–13 years old and their families.

Methods

Study population

The 'Healthy Growth Study' was a large cross-sectional epidemiologic study, which was in accordance with the Declaration of Helsinki and was approved by the Greek Ministry of National Education and the Ethics Committee of Harokopio University of Athens. The study was initiated in May 2007 and completed in June 2009 and its population comprised of 5th and 6th grade schoolchildren of 77 primary schools in the counties of Attica, Aetoloakarnania, Thessaloniki and Iraklion. The sampling of municipalities and schools in the present study was random, multi-stage and stratified by the parental educational level and the total population of pre-adolescent students, thus yielding a representative sample of primary-school children from the wider urban region of Athens. More specifically, the municipalities in the county of Attica were divided into three groups based on the average educational level of their adult population (25–65-year-olds) that was estimated from data provided by the National Statistical Service of Greece. This procedure yielded two parental education cut-off points that allowed us to categorize municipalities into three categories of different socio-economic levels (SEL), i.e. higher, medium and lower SEL. Consequently, based on data from the National Statistical Service of Greece, a certain number of municipalities, proportional to the size of their pre-adolescent population (9–14-year-olds), were randomly selected from each of these three SEL groups. Finally, an appropriate number of schools were randomly selected from each of these municipalities in relation to the population of schoolchildren registered in the fifth and sixth grades in each municipality, based on data obtained from the Greek Ministry of Education. An extended letter explaining the aims of the present study and a consent form for taking full measurements were provided to all parents or guardians having a child in the participating schools, in accordance with the Declaration of Helsinki 1964 and its later amendments. Parents who agreed to the participation of their children in the study had to sign the consent form and provide their contact details. Signed parental consent forms were collected for 2655 out of 4145 children (64.1%).

Assessment of blood pressure

No child was receiving blood pressure (BP) lowering drugs. Assessment of BP was performed in the right brachial artery using a mercury sphygmomanometer after the child was left seated and quiet for 5 min. Assessment of the mid-upper arm circumference was performed before the blood pressure screening and different cuff sizes were used as appropriate. The 1st and 5th Korotkoff sound were used for the identification of the systolic and diastolic BP level. Two consecutive measurements were performed for each child, with a 2-min interval and if the pressure readings differed by more than 10 mmHg, an additional measurement was carried out. Mean value from two or three consecutive readings of SBP and DBP taken from each child was used. BP between the 90th and 95th percentile was characterized as "high normal" or "pre-hypertension" and "Systolic and/or Diastolic BP" was defined as average SBP and/or DBP $\geq$ 95th percentile for gender, age and height. Additionally BP between 95th and 99th percentile plus 5 mmHg was "stage 1 hypertension" and BP above 99th percentile plus 5 mmHg was "stage 2 hypertension" [15]. Existence of hypertension was considered for children categorized as having stage 1 or stage 2 hypertension. Children with normal or high normal blood pressure were considered as not having hypertension.

Anthropometry

Two trained members of the research team performed all anthropometric measurements using a standard protocol and the same equipment, which has been extensively described previously [16]. The International Obesity Task Force (IOTF) cut-off points were used to categorize participants as normal-weight, overweight or obese. The International Diabetes Foundation criteria for children and adolescents were used for the definition of central obesity. In specific children $\geq$ 90th percentile were considered as being centrally obese [17]. Furthermore, one well-trained and experienced pediatrician in each prefecture determined pubertal maturation (Tanner stage) after thorough visual inspection of breast development in girls and genital development in boys.

Family socio-demographic and perinatal data

Data regarding socio-demographic status, parental weight and height and perinatal information were reported by the parents or taken from the children's birth certificates and medical records provided by the parents during their scheduled interviews. For approximately 5% of the parents (N = 133) who were unable to attend, data were collected via telephone interviews using standardized questionnaire by trained members of the research team. In those cases parents reported all necessary data using the birth certificates of their children. The information collected included: father's and mother's age (grouped in tertiles), self-reported parental weight and height from which BMI was calculated, parental years of education (stratified into less than 9 years, which is the duration of compulsory education in Greece that leads to a Junior High School degree, 9–12 years of education corresponding to having a High School degree and >12 years of education corresponding to having a College or a University degree), parental hypertension and smoking, parental and child nationality, parental marital status (two-parent families, single-parent families), mean annual family income over the past 3 years, mother's current employment status and number of cars owned by the family and household size (m^2/family member). Mothers were asked to recall the following perinatal information: type of conception, medical history of gestational diabetes mellitus and high blood pressure, smoking and weight gained during pregnancy based on the classification recommended by the IOM, and parity.

The following information was taken from each child's birth certificate and medical record: birth date for the estimation of the exact age of each child, birth weight and gestational age for the classification into small for gestational age (SGA, <10th percentile), appropriate for gestational age (AGA, 10th to 89th percentile) and large for gestational age (LGA, $\geq$90th percentile), change in weight-for-length from birth to 6 months of age for the classification into poor (<-1 z score), average (-1 to $+1$ z score), and rapid ($>+1$ z score), weight gain during infancy, type of delivery (normal *vs.* cesarean), feeding pattern from birth to 6 months of age, i.e., breastfeeding and age of solid food introduction.

Lifestyle factors

Dietary intake

Dietary intake data were obtained by trained dieticians and nutritionists via morning interviews with the children at the school-site regarding two consecutive weekdays and one weekend day, using the 24-h recall technique. All relevant procedures regarding dietary intake assessment and analysis of food intake into daily energy intake, macro and micronutrient consumption has been described in detail previously [18]. Daily energy intake was expressed as percentage of Estimated Energy Requirements. Sodium, potassium and fiber intake were dichotomized by the relevant dietary reference values (DRV's). Fruits and vegetables consumption was dichotomized by daily intake of less or more than 5. Sodium to potassium ratio was estimated by the sodium and potassium daily intake and it was dichotomized by the median.

Sleep time

Also, parents were asked to report the time their children usually go to bed at night and wake up in the morning on weekdays and weekend days, respectively. This information was used for the calculation of children's night sleep duration.

Physical activity

Time and intensity of physical activity

Physical activities of different intensity during leisure time was assessed using a standardized activity interview, based on a standardized questionnaire filled out by the participants via interviews from a member of the research team [19]. Respondents reported the time spent on various physical activities or organized sports on two weekdays and one weekend day, most preferably Sunday. Details on the procedures followed to subjectively assess children's physical activity levels are described elsewhere [18].

Step count

The objective assessment of children's physical activity was conducted via a waist-mounted pedometer (Yamax SW-200 Digiwalker; Yamax Corporation, Tokyo, Japan) for 1 week (i.e. from Monday to Sunday) following a standard procedure described in details previously [16].

Screen time

Children's screen time (i.e. time spent on viewing television/video and playing computer games) was assessed by children's report with regard to a usual weekday and a usual weekend. The mean daily screen time was calculated using the following equation: daily screen time = [(weekday screen time x 2.5) + weekend screen time]/7.

Statistical analyses

Normality of the data was assessed through one-sample Kolmogorov–Smirnov tests. All continuous variables are presented as mean values (standard deviation) and categorical variables as frequencies. Furthermore, in order to examine the associations of perinatal, socio-demographic and lifestyle indices with existence of hypertension, univariate logistic regression analyses were performed. To test whether the significant associations observed at a univariate level were independent, multivariate logistic regression analyses were also performed. Crude and adjusted odds ratios (OR) with 95% confidence intervals (CI) were computed from the univariate and the multivariate regression analyses, respectively. Missing values were not filled out with any known method and in the present analysis we used only those children that had full data for all the variables included in the analysis. The level of statistical significance was set at $P < 0.05$. The Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA), version 21·0, was used for all analyses.

Results

The present study used all the available parameters (N = 43), known to directly or indirectly relate to childhood and adolescence hypertension. Also a small number of other variables (i.e. parity) were used. These variables though never examined before in relation to childhood and adolescence hypertension, they are considered to affect the child's conditions of living, like engagement in physical activities, food availability and preferences. The study sample comprised of 1444 early adolescents 9–13 years old who had full data of all 43 perinatal, socioeconomic, anthropometric and lifestyle parameters used in the statistical analysis. Table 1 presents the main characteristics of the study participants. Their mean age was 11.12 ± 0.67 years, 48.8% were boys and 25.2% and 7% were overweight or obese respectively.

Table 2–4 present the univariate associations of perinatal, socio-demographic and lifestyle indices respectively with existence of either systolic or diastolic hypertension in early adolescents. Findings from these analyses showed that girls (OR, 95% C.I. 1.32 (1.02–1.72)) and children with rapid growth velocity during the first six months of their lives (OR, 95% C.I. 1.35 (1.02–1.79) had higher risk of hypertension, while LGA children had lower risk of hypertension (OR, 95% C.I. 0.51 (0.28–0.92)). Early adolescents living with one of the two parents (single-parent family) (OR, 95% C.I. 0.58 (0.35–0.96)) and those of higher socioeconomic status (SES) (OR, 95% C.I. 0.55 (0.37–0.82)) had lower risk of hypertension, while those whose father had hypertension (OR, 95% C.I. 1.76 (1.14–2.73)) or their mother was obese (OR, 95% C.I. 1.91 (1.31–2.78)) had higher hypertension risk. Also, early adolescents with more time spent on MVPA (OR, 95% C.I. 0.68 (0.52–0.88)) and those having more steps/day (OR, 95% C.I. 0.70 (0.54–0.91)), as well as those with higher daily energy intake (OR, 95% C.I. 0.73 (0.54–0.99)) had lower risk of hypertension. Moreover, overweight and obese early adolescents (OR, 95% C.I. 2.61 (1.88–3.62)) and those having central obesity (OR, 95% C.I. 3.58 (2.48–5.22)) had increased risk of hypertension.

Table 1 Characteristics of study population.

	Total sample (n = 1444)		
	Mean		SD
Age (years)	11.12		0.67
Boys (%)		48.8	
BMI (kg/m^2)	19.51		3.38
Waist circumference (cm)	66.81		8.52
Weight categories			
Normal-weight (%)		67.9	
Overweight (%)		25.2	
Obese (%)		7.0	
SBP (mmHg)	112.29		12.47
DBP (mmHg)	69.75		8.64
Hypertension (%)		20.7	
Tanner stage			
Stage 1 (%)		33.8	
Stage 2 (%)		41.9	
Stage 3 (%)		17.9	
Stage 4 (%)		5.4	
Stage 5 (%)		1.0	
Daily energy intake (kcal/day)	1971.95		500.48

BMI: body mass index, SBP: systolic blood pressure, DBP: diastolic blood pressure.

Table 5 presents the multivariate associations of those perinatal, socio-demographic and lifestyle indices found to be associated with hypertension at the univariate level. The same variables were also inserted in a multivariate analysis testing their association with existence of either systolic or diastolic hypertension using continuous data wherever possible (Supplemental Table 1). LGA children (OR, 95% C.I. 0.49 (0.25–0.97)), those with higher MVPA (OR, 95% C.I. 0.71 (0.53–0.96)) and with higher SES (OR, 95% C.I. 0.51 (0.33–0.79)) had lower risk of hypertension independently of all the other variables used in the multivariate model. On the other hand, overweight and obese early adolescents (OR, 95% C.I. 2.61 (1.88–3.62)), those with central obesity (OR, 95% C.I. 1.75 (1.12–2.73)) and those whose father was hypertensive (OR, 95% C.I. 1.93 (1.20–3.12)) had a higher risk of hypertension.

Discussion

The present study investigated simultaneously the possible associations of 43 different perinatal, socio-demographic, parental anthropometric and early adolescents' lifestyle characteristics with childhood hypertension. Also, the present study aimed to investigate characteristics associated with hypertension, independently from all tested parameters, in order to identify the

Table 2 Logistic regression analysis for the associations between several perinatal factors (independent variables) and systolic or diastolic blood pressure (dependent variables).

Independent variables	Cases (% of total)	Odds ratio (95% confidence interval) Dependent Variables SBP or DBP	p value
Type of conception			
Normal	1400 (97.0)	1.00	
In vitro fertilization (IVF)	44 (3.0)	1.04 (0.49–2.21)	0.91
Gestational weight gain			
Within IOM recommendation	475 (32.9)	1.00	
Below IOM recommendation	513 (35.5)	0.92 (0.67–1.26)	0.59
Above IOM recommendation	456 (31.6)	1.05 (0.77–1.45)	0.76
Maternal smoking during pregnancy			
No smoking	1223 (84.7)	1.00	
1st trimester	29 (2.0)	1.22 (0.51–2.89)	0.65
2nd trimester	3 (0.2)	7.66 (0.69–84.79)	0.10
3rd trimester	19 (1.3)	1.47 (0.52–4.17)	0.47
1st trimester and 2nd trimester	9 (0.6)	0.48 (0.06–3.85)	0.49
2nd trimester and 3rd trimester	18 (1.2)	0.88 (0.25–3.13)	0.85
All trimesters	143 (9.9)	0.91 (0.58–1.41)	0.67
Gender			
Boys	705 (48.8)	1.00	
Girls	739 (51.2)	**1.32 (1.02–1.72)**	**0.04**
High blood pressure during pregnancy			
No	1359 (94.4)	1.00	
Yes	47 (3.3)	1.36 (0.70–2.66)	0.37
Not known	33 (2.3)	1.04 (0.45–2.42)	0.93
Diabetes mellitus during pregnancy			
No	1360 (94.5)	1.00	
Yes	43 (3.0)	1.51 (0.76–2.97)	0.24
Not known	36 (2.5)	1.30 (0.60–2.79)	0.51
Gestational age (weeks)			
<37	239 (16.6)	1.00	
≥37	1205 (83.4)	0.92 (0.65–1.30)	0.63
Parity			
Uniparous	695 (48.1)	1.00	
Multiparous	749 (51.9)	0.87 (0.67–1.12)	0.28
Birth weight for gestational age			
Appropriate (10th–89th percentile)	1167 (80.8)	1.00	
Small (<10th percentile)	165 (11.4)	1.37 (0.93–2.00)	0.11
Large (>90th percentile)	112 (7.8)	**0.51 (0.28–0.92)**	**0.03**
Type of delivery			
Normal	1017 (70.5)	1.00	
Cesarean	426 (29.5)	0.90 (0.68–1.20)	0.48
Weight gain in the first 6 months			
Average (−1 to +1 z-score change)	837 (58.9)	1.00	
Poor (<−1 z-score change)	144 (10.1)	0.70 (0.42–1.17)	0.17
Rapid (>+1 z-score change)	441 (31.0)	**1.35 (1.02–1.79)**	**0.03**
Breastfeeding			
Not exclusive	1313 (90.9)	1.00	
Exclusive	131 (9.1)	0.92 (0.58–1.46)	0.73
Time of solid food initiation			
≤4 months	252 (17.5)	1.00	
5–6 months	952 (66.0)	1.06 (0.74–1.51)	0.75
>6 months	238 (16.5)	1.37 (0.89–2.13)	0.16

SBP: systolic blood pressure, DBP: diastolic blood pressure, IOM: Institute of Medicine.
Bold font indicates statistically significant OR ($P < 0.05$).

most dominant perinatal, sociodemographic and lifestyle correlates of this health problem. Therefore, independently from all characteristics tested, early adolescents born LGA, more physically active and of a higher SES had lower risk of hypertension. Also, overweight and obese early adolescents those with central obesity and with a hypertensive father, had higher risk of hypertension.

According to univariate models, several parameters were separately associated with early adolescence hypertension. Regarding sex, few previous studies have shown that boys are more susceptible to hypertension than girls, mostly attributed to higher abdominal adiposity [8,20], which is in opposition to the present findings. However, there are also other studies reporting

Table 3 Logistic regression analysis for the associations between several socio-demographic factors (independent variables) and systolic or diastolic blood pressure (dependent variables).

Independent Variables	Cases (% of total)	Odds ratio (95% confidence interval)	p value
		Dependent Variables	
		SBP or DBP	
Age categories			
9–11 years	644 (44.6)	1.00	
11–13 years	800 (55.4)	0.80 (0.62–1.04)	0.09
Nationality			
Greek	1204 (83.4)	1.00	
Non-Greek	240 (16.6)	0.90 (0.63–1.28)	0.56
Family status			
Two-parent families	1229 (90.0)	1.00	
Single-parent families	145 (10.0)	**0.58 (0.35–0.96)**	**0.03**
Mother's Age			
<38 years	570 (39.6)	1.00	
38–42 years	471 (32.7)	1.21 (0.89–1.64)	0.23
>42 years	399 (27.7)	1.05 (0.76–1.45)	0.79
Father's Age			
<42 years	540 (37.6)	1.00	
42–46 years	453 (31.6)	0.78 (0.57–1.06)	0.11
>46 years	442 (30.8)	0.75 (0.54–1.02)	0.07
Family income (euro/year)			
<12,000	315 (21.8)	1.00	
12,000–30,000	735 (50.9)	0.98 (0.70–1.36)	0.88
>30,000	394 (27.3)	0.96 (0.66–1.39)	0.83
Paternal education			
<9 years	345 (23.9)	1.00	
9–12 years	553 (38.3)	1.09 (0.78–1.53)	0.62
>12 years	546 (37.8)	1.02 (0.73–1.44)	0.90
Maternal education			
<9 years	282 (19.5)	1.00	
9–12 years	564 (39.1)	0.93 (0.66–1.33)	0.70
>12 years	598 (41.4)	0.84 (0.59–1.19)	0.32
Maternal employment status			
Unemployed	454 (31.4)	1.00	
Employed	990 (68.6)	1.07 (0.81–1.42)	0.63
Family cars			
0	554 (38.4)	1.00	
1	487 (33.7)	1.29 (0.95–1.73)	0.10
2	363 (25.1)	0.86 (0.61–1.22)	0.40
>3	40 (2.8)	0.61 (0.23–1.59)	0.31
Paternal hypertension			
Not known/No	1334 (92.4)	1.00	
Yes	110 (7.6)	**1.76 (1.14–2.73)**	**0.01**
Maternal hypertension			
Not known/No	1295 (96.8)	1.00	
Yes	43 (3.2)	1.82 (0.93–3.55)	0.08
Household size (m^2/family member)			
<20	546 (38.7)	1.00	
20–25	372 (26.4)	**0.69 (0.50–0.96)**	**0.03**
25–30	244 (17.3)	0.69 (0.47–1.01)	0.06
>30	248 (17.6)	**0.55 (0.37–0.82)**	**0.003**

SBP: systolic blood pressure, DBP: diastolic blood pressure.
Bold font indicates statistically significant OR ($P < 0.05$).

that the prevalence of hypertension is higher in girls than in boys [21], which imply that girls might be at a higher risk for hypertension. To the best of our knowledge, there is no previous study investigating associations between growth velocity in the first 6 months of age and childhood hypertension and therefore it is not easy to compare or explain the present findings. Nevertheless, these findings are in accordance with few published studies showing a positive association of rapid growth in children's life (after the first 6 months), with childhood and adulthood hypertension [22,23].

The positive association of paternal hypertension with early adolescence hypertension found in the present study has already been described [24], although it has also been stated previously that maternal hypertension may be a stronger risk factor than paternal hypertension. A possible

Table 4 Logistic regression analysis for the associations between parental anthropometrics, children's anthropometric, dietary and physical activity indices (independent variables) and systolic or diastolic blood pressure (dependent variables).

Independent Variables	Cases (% of total)	Odds ratio (95% confidence interval)	p value
		Dependent Variables	
		SBP or DBP	
Mother's BMI			
Under/Normal-weight	888 (61.7)	1.00	
Overweight	389 (27.0)	1.21 (0.89–1.63)	0.22
Obese	163 (11.3)	**1.91 (1.31–2.78)**	**0.001**
Father's BMI			
Under/Normal-weight	389 (27.1)	1.00	
Overweight	767 (53.5)	1.04 (0.77–1.42)	0.80
Obese	278 (19.4)	1.13 (0.77–1.66)	0.52
Maternal smoking			
No	912 (63.6)	1.00	
Yes	522 (36.4)	1.00 (0.76–1.31)	0.99
Paternal smoking			
No	701 (51.6)	1.00	
Yes	657 (48.4)	1.20 (0.92–1.57)	0.18
Early adolescent's moderate to vigorous physical activity			
<60 min per day	766 (53.0)	1.00	
>60 min per day	678 (47.0)	**0.68 (0.52–0.88)**	**0.004**
Early adolescent's organized moderate to vigorous physical activity levels			
<30 min per day	979 (68.6)	1.00	
>30 min per day	449 (31.4)	1.09 (0.83–1.44)	0.53
Early adolescent's TV time			
<2 h per day	722 (50.7)	1.00	
>2 h per day	702 (47.3)	1.04 (0.80–1.34)	0.80
Early adolescent's number of steps per day			
<12,000 steps (girls), <13,000 (boys)	722 (50.0)	1.00	
≥12,000 steps (girls), ≥13,000 (boys)	721 (50.0)	**0.70 (0.54–0.91)**	**0.01**
Early adolescent's sleep time			
Zero tertile	396 (27.6)	1.00	
1st tertile	510 (35.5)	0.95 (0.69–1.32)	0.77
2nd tertile	529 (36.9)	0.93 (0.67–1.28)	0.65
Early adolescent's weight status			
Underweight/normal-weight	976 (67.9)	1.00	
Overweight/obese	462 (32.1)	**3.20 (2.45–4.18)**	**0.00**
Early adolescent's central obesity			
Normal waist circumference	1302 (90.7)	1.00	
Central obesity	134 (9.3)	**3.58 (2.48–5.22)**	**0.00**
Early adolescent's total energy intake %EER[a]			
80–120%	848 (59.5)	1.00	
<80%	145 (10.2)	1.35 (0.90–2.04)	0.15
>120%	433 (30.4)	**0.73 (0.54–0.99)**	**0.04**
Early adolescent's sodium intake			
< DRVs[b]	355 (24.6)	1.00	
>DRVs[b]	1088 (75.4)	1.01 (0.74–1.35)	0.99
Early adolescent's potassium intake			
<DRVs[c]	597 (41.4)	1.00	
>DRVs[c]	846 (58.6)	0.95 (0.73–1.23)	0.67
Sodium-to- potassium ratio			
Below the median	688 (47.6)	1.00	
Above the median	756 (52.4)	0.80 (0.62–1.04)	0.09
Early adolescent's fiber intake[d]			
<DRVs	1420 (98.3)	1.00	
>DRVs	24 (1.7)	0.99 (0.37–2.72)	0.99
Early adolescent's fruits and vegetables intake			
<5 fruits and vegetables per day	1297 (92.3)	1.00	
>5 fruits and vegetables per day	108 (7.7)	0.86 (0.52–1.43)	0.56

SBP: systolic blood pressure, DBP: diastolic blood pressure.
Bold font indicates statistically significant OR ($P < 0.05$).
[a] EER: Estimated Energy Requirements.
[b] 1300 mg, which is the mean dietary reference value (DRV) for age groups 7–10 and 11–14.
[c] 2250 mg, which is the mean dietary reference value (DRV) for age groups 7–10 and 11–14.
[d] 19 gr/day which is the mean dietary reference value (DRV) for age groups 7–10 and 11–14.

Table 5 Multiple logistic regression analysis for the associations between perinatal factors, socio-demographic factors, parental anthropometrics, children's anthropometric, dietary and physical activity indices (independent variables) and systolic or diastolic blood pressure (dependent variables).

Independent Variables	Odds ratio (95% confidence interval)	p value
	Dependent Variables	
	SBP or DBP	
Gender		
Boys	1.00	
Girls	1.30 (0.97–1.75)	0.08
Birth weight for gestational age		
Appropriate (10th-89th percentile)	1.00	
Small (<10th percentile)	1.46 (0.93–2.28)	0.10
Large (>90th percentile)	**0.49 (0.25–0.97)**	**0.04**
Weight gain in the first 6 months		
Average (−1 to +1 z-score change)	1.00	
Poor (<−1 z-score change)	0.68 (0.39–1.18)	0.17
Rapid (>+1 z-score change)	1.04 (0.75–1.44)	0.81
Early adolescent's weight status		
Underweight/normal-weight	1.00	
Overweight/obese	**2.61 (1.88–3.62)**	**0.00**
Early adolescent's central obesity		
Normal waist circumference	1.00	
Central obesity	**1.75 (1.12–2.73)**	**0.01**
Early adolescent's moderate to vigorous physical activity		
<60 min per day	1.00	
>60 min per day	**0.71 (0.53–0.96)**	**0.03**
Early adolescent's number of steps per day		
<12,000 steps (girls), <13,000 (boys)	1.00	
≥12,000 steps (girls), ≥13,000 (boys)	0.92 (0.68–1.23)	0.56
Early adolescent's total energy intake %EER		
80–120%	1.00	
<80%	1.18 (0.74–1.88)	0.49
>120%	0.90 (0.65–1.26)	0.55
Family status		
Two-parent families	1.00	
Single-parent families	0.59 (0.34–1.01)	0.06
Paternal hypertension		
Not known/No	1	
Yes	**1.93 (1.20–3.12)**	**0.01**
Household size (m^2/family member)		
<20	1.00	
20–25	**0.68 (0.48–0.97)**	**0.04**
25–30	**0.66 (0.44–0.99)**	**0.04**
>30	**0.51 (0.33–0.79)**	**0.002**
Mother's BMI		
Under/Normal-weight	1.00	
Overweight	1.01 (0.73–1.40)	0.97
Obese	1.39 (0.92–2.12)	0.12

BMI: body mass index, SBP: systolic blood pressure, DBP: diastolic blood pressure, EER: Estimated Energy Requirements.
Bold font indicates statistically significant OR ($P < 0.05$).

mechanism regarding this association is that offspring of hypertensive parents were found to have higher levels of arterial stiffness and sympathetic system activity [25,26]. In addition, parental excess body weight has been previously associated with higher risk of childhood hypertension through genetic, biological, or environmental influences, which is in line with the present outcome regarding maternal obesity [27].

There are also a number of large epidemiologic studies highlighting the positive associations of children's overweight and obesity with elevated blood pressure [28,29]. The etiology of obesity-related hypertension in children and adolescents appears to be linked to sympathetic hyperactivity and insulin resistance, leading to alterations in vascular reactivity and decreased sodium excretion [30]. However, there is also an indirect relation of childhood hypertension with other obesity-related factors such as presence of low-grade inflammation [31,32], preclinical atherosclerosis [33] and habitual consumption of food choices rich in sodium and added sugars [31,34]. Regarding LGA, it has not been previously associated with childhood hypertension. Most published studies highlight SGA as being positively associated with increased levels of hypertension in children and adolescents [35,36]. Therefore, we may hypothesize that perhaps LGA may be more protective than SGA in relation to hypertension risk. However, this needs to be elucidated in the future.

There has been no previous study investigating the associations of living in single-parent families with childhood and early adolescence hypertension. However, there are a few studies supporting the inverse association of SES with childhood hypertension [10,37]. Children of low-SES families are likely to have worse health outcomes, as they are more likely engaged in unhealthy behaviors like poor and unhealthy diet, absence of physical activities leading to excess body weight [37]. Also, there are studies supporting the inverse association between levels of physical activity and childhood hypertension, also found in the present study [12,38]. Exercise in children increases secretion of vasodilator substances, such as nitric oxide, leading to dilation of the blood vessels and, consequently, reduced peripheral vascular resistance [12,39]. Also, it reduces catecholamine levels and increases insulin sensitivity, both of which have been associated with reduced sodium and water retention leading to lower BP [40]. Finally, high energy intake was inversely associated with hypertension risk in the univariate model, which is not in accordance with the previously described association of excess body weight and hypertension; however, it is possible that this univariate association is mediated by other factors such as physical activity.

Results from the multivariate model showed that among the already mentioned perinatal, socio-demographic and lifestyle characteristics tested, those with an independent association with early adolescence hypertension are: non LGA, low socioeconomic status, paternal hypertension, low physical activity, overweight or obesity and central obesity. It is evident from the present findings that early adolescents' overweight and obesity, as well as central obesity, are among the strongest correlates of hypertension. As already mentioned, till now, several mechanisms have been described to explain this relation. It was reported that children with excess body weight have sympathetic hyperactivity [11], insulin resistance, higher levels of circulating leptin, aldosterone and inflammation markers [41], all of which have been associated with childhood hypertension, as well as endothelial dysfunction [33]. Therefore, the strong association of childhood and adolescent's overweight and obesity with hypertension is fully justified.

Till present a number of published studies have investigated the separate association of a number of lifestyle but only a few perinatal and socio-demographic factors, with childhood hypertension. Although this piece of information has been very helpful in shaping prevention programs, there was no study assessing the most dominant perinatal, socio-demographic and lifestyle characteristics associated with early adolescence hypertension. The present study highlighted among 43 different perinatal, socio-demographic, parental anthropometric and early adolescents' lifestyle characteristics, those independently associated with hypertension in early adolescence, pointing out the most dominant correlates of this health problem. Future prevention programs should take into consideration all factors identified in the present study to detect early adolescents and their families with the highest possible risk of hypertension. Therefore, future programs for timely prevention of early adolescence hypertension could prioritize the most vulnerable population groups, which are low SES families with overweight and obese early adolescents, born non LGA, having low levels of physical activity and with a family history of hypertension.

The present study has both strengths and limitations. The Healthy Growth Study is a large epidemiologic study conducted in Greek children. The main limitation was the single-visit assessment of SBP and DBP, instead of home or ambulatory blood pressure measurements. This was because of the cross-sectional design of the present study and the implementation of all measurements in school, not allowing for the BP assessment to be conducted in a better controlled clinical environment. Also, being a cross-sectional study does not allow any causal associations. Additionally, we cannot exclude the possibility of maternal recall bias in gathering information regarding pregnancy data. Also, this is a regionally representative study conducted in Greece and use of children having full data for 43 variables made the study sample even smaller, which prevail generalizability of the findings.

Conclusions

Among the parameters examined, early adolescents' abnormal weight status and central obesity, low levels of physical activity, born non LGA and coming from low SES family with family history of hypertension, are independent risk factors for early adolescence hypertension. Future public health initiatives should focus on the identified correlates of early adolescence hypertension in order to prioritize early adolescents and families at the highest possible risk, for early detection and management of this health problem.

Conflicts of interest

None.

Source of funding

This research has been co-financed by the European Union (European Social Fund — ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Heraclitus II. Investing in knowledge society through the European Social Fund. The funder had no involvement in any decision made regarding the study (design, data collection, interpretation, writing of the paper or manuscript submission).

Acknowledgements

The authors would like to thank the "Healthy Growth Study" group for the valuable contribution to the completion of the study.

Healthy Growth Study Group

Harokopio University Research Team/Department of Nutrition and Dietetics: Yannis Manios (Coordinator), George Moschonis (Project manager), Katerina P. Skenderi, Evangelia Grammatikaki, Odysseas Androutsos, Sofia Tanagra, Alexandra Koumpitski, Paraskevi-Eirini Siatitsa, Anastasia Vandorou, Aikaterini-Efstathia Kyriakou, Vasiliki Dede, Maria Kantilafti, Aliki-Eleni Farmaki, Aikaterini Siopi, Sofia Micheli, Louiza Damianidi, Panagiota Margiola, Despoina Gakni, Vasiliki Iatridi, Christina Mavrogianni, Kelaidi Michailidou, Aggeliki Giannopoulou, Efstathoula Argyri, Konstantina Maragkopoulou, Maria Spyridonos, Eirini Tsikalaki, Panagiotis Kliasios, Anthi Naoumi, Konstantinos Koutsikas, Epistimi Aggelou, Zoi Krommyda, Charitini Aga, Manolis Birbilis, Ioanna Kosteria, Amalia Zlatintsi, Elpida Voutsadaki, Eleni-Zouboulia Papadopoulou, Zoi Papazi, Maria Papadogiorgakaki, Fanouria Chlouveraki, Maria Lyberi, Nora Karatsikaki-Vlami, Eva Dionysopoulou, Efstratia Daskalou.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.numecd.2018.10.007.

References

[1] Rosner B, Cook NR, Daniels S, Falkner B. Childhood blood pressure trends and risk factors for high blood pressure: the NHANES experience 1988-2008. Hypertension 2013 Aug;62(2):247–54.
[2] Martin L, Oepen J, Reinehr T, Wabitsch M, Claussnitzer G, Waldeck E, et al. Ethnicity and cardiovascular risk factors: evaluation of 40,921 normal-weight, overweight or obese children and adolescents living in Central Europe. Int J Obes (Lond) 2015;39(1): 45–51.
[3] Karatzi K, Protogerou AD, Moschonis G, Tsirimiagou C, Androutsos O, Chrousos GP, et al. Prevalence of hypertension and hypertension phenotypes by age and gender among schoolchildren in Greece: the Healthy Growth Study. Atherosclerosis 2017;259:128–33.
[4] Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. Circulation 2008;117(25):3171–80.
[5] Litwin M, Niemirska A, Sladowska-Kozlowska J, Wierzbicka A, Janas R, Wawer ZT, et al. Regression of target organ damage in children and adolescents with primary hypertension. Pediatr Nephrol 2010;25(12):2489–99.
[6] Dello Russo M, Ahrens W, De Vriendt T, Marild S, Molnar D, Moreno LA, et al. Gestational weight gain and adiposity, fat distribution, metabolic profile, and blood pressure in offspring: the IDEFICS project. Int J Obes (Lond) 2013;37(7):914–9.
[7] Staley JR, Bradley J, Silverwood RJ, Howe LD, Tilling K, Lawlor DA, et al. Associations of blood pressure in pregnancy with offspring blood pressure trajectories during childhood and adolescence: findings from a prospective study. J Am Heart Assoc 2015;4(5).
[8] de Moraes AC, Lacerda MB, Moreno LA, Horta BL, Carvalho HB. Prevalence of high blood pressure in 122,053 adolescents: a systematic review and meta-regression. Medicine (Baltimore) 2014;93(27):e232.
[9] Othman AS, Othman NI, Rosman A, Nudin SS, Rahman AR. Central and peripheral blood pressure profile of young offspring with hypertensive and normotensive parents. J Hypertens 2012;30(8):1552–5.
[10] van den Berg G, van Eijsden M, Galindo-Garre F, Vrijkotte TG, Gemke RJ. Explaining socioeconomic inequalities in childhood blood pressure and prehypertension: the ABCD study. Hypertension 2013;61(1):35–41.
[11] Wirix AJ, Kaspers PJ, Nauta J, Chinapaw MJ, Kist-van Holthe JE. Pathophysiology of hypertension in obese children: a systematic review. Obes Rev 2015;16(10):831–42.
[12] de Moraes AC, Carvalho HB, Siani A, Barba G, Veidebaum T, Tornaritis M, et al. Incidence of high blood pressure in children - effects of physical activity and sedentary behaviors: the IDEFICS study: high blood pressure, lifestyle and children. Int J Cardiol 2015;180:165–70.
[13] Shi L, Krupp D, Remer T. Salt, fruit and vegetable consumption and blood pressure development: a longitudinal investigation in healthy children. Br J Nutr 2014;111(4):662–71.
[14] Simonetti GD, Schwertz R, Klett M, Hoffmann GF, Schaefer F, Wuhl E. Determinants of blood pressure in preschool children: the role of parental smoking. Circulation 2011;123(3):292–8.
[15] National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Pediatrics 2004;114(2 Suppl 4th Report):555–76.
[16] Moschonis G, Kaliora AC, Karatzi K, Michaletos A, Lambrinou CP, Karachaliou AK, et al. Perinatal, sociodemographic and lifestyle correlates of increased total and visceral fat mass levels in schoolchildren in Greece: the Healthy Growth Study. Publ Health Nutr 2017;20(4):660–70.
[17] Fernandez JR, Redden DT, Pietrobelli A, Allison DB. Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. J Pediatr 2004;145(4):439–44.
[18] Moschonis G, Mavrogianni C, Karatzi K, Iatridi V, Chrousos GP, Lionis C, et al. Increased physical activity combined with more eating occasions is beneficial against dyslipidemias in children. The Healthy Growth Study. Eur J Nutr 2013;52(3):1135–44.
[19] Manios Y, Kafatos A, Markakis G. Physical activity in 6-year-old children: validation of two proxy reports. Pediatr Exerc Sci 1998; 10:176–88.
[20] Pires A, Martins P, Pereira AM, Marques M, Castela E, Sena C, et al. Childhood adiposity: being male is a potential cardiovascular risk factor. Eur J Pediatr 2016;175(1):63–9.
[21] Schwandt P, Scholze JE, Bertsch T, Liepold E, Haas GM. Blood pressure percentiles in 22,051 German children and adolescents: the PEP Family Heart Study. Am J Hypertens 2015;28(5):672–9.
[22] Grijalva-Eternod CS, Lawlor DA, Wells JC. Testing a capacity-load model for hypertension: disentangling early and late growth effects on childhood blood pressure in a prospective birth cohort. PLoS One 2013;8(2):e56078.
[23] Sabo RT, Wang A, Deng Y, Sabo CS, Sun SS. Relationships between childhood growth parameters and adult blood pressure: the Fels Longitudinal Study. J Dev Orig Health Dis 2017;8(1):113–22.
[24] Rodriguez-Moran M, Aradillas-Garcia C, Simental-Mendia LE, Monreal-Escalante E, de la Cruz Mendoza E, Davila Esqueda ME, et al. Family history of hypertension and cardiovascular risk factors in prepubertal children. Am J Hypertens 2010;23(3):299–304.
[25] Dernellis J, Panaretou M. Aortic stiffness in children of parents with hypertension. J Hum Hypertens 2006;20(3):225–6.
[26] Rathi P, Agarwal V, Kumar A. Sympathetic hyperactivity in children of hypertensive parents. Ann Neurosci 2013;20(1):4–6.
[27] Labayen I, Ruiz JR, Ortega FB, Loit HM, Harro J, Veidebaum T, et al. Intergenerational cardiovascular disease risk factors involve both maternal and paternal BMI. Diabetes Care 2010;33(4):894–900.
[28] Parker ED, Sinaiko AR, Kharbanda EO, Margolis KL, Daley MF, Trower NK, et al. Change in weight status and development of hypertension. Pediatrics 2016;137(3):e20151662.
[29] Xu RY, Zhou YQ, Zhang XM, Wan YP, Gao X. Body mass index, waist circumference, body fat mass, and risk of developing hypertension in normal-weight children and adolescents. Nutr Metab Cardiovasc Dis 2018;28(10):1061–6.

[30] Anyaegbu EI, Dharnidharka VR. Hypertension in the teenager. Pediatr Clin North Am 2014;61(1):131–51.

[31] Feber J, Ahmed M. Hypertension in children: new trends and challenges. Clin Sci (Lond) 2010;119(4):151–61.

[32] Syrenicz A, Garanty-Bogacka B, Syrenicz M, Gebala A, Dawid G, Walczak M. Relation of low-grade inflammation and endothelial activation to blood pressure in obese children and adolescents. Neuroendocrinol Lett 2006;27(4):459–64.

[33] Aggoun Y, Farpour-Lambert NJ, Marchand LM, Golay E, Maggio AB, Beghetti M. Impaired endothelial and smooth muscle functions and arterial stiffness appear before puberty in obese children and are associated with elevated ambulatory blood pressure. Eur Heart J 2008;29(6):792–9.

[34] Kell KP, Cardel MI, Bohan Brown MM, Fernandez JR. Added sugars in the diet are positively associated with diastolic blood pressure and triglycerides in children. Am J Clin Nutr 2014;100(1):46–52.

[35] Zarrati M, Shidfar F, Razmpoosh E, Nezhad FN, Keivani H, Hemami MR, et al. Does low birth weight predict hypertension and obesity in schoolchildren? Ann Nutr Metab 2013;63(1–2):69–76.

[36] Bonamy AK, Kallen K, Norman M. High blood pressure in 2.5-year-old children born extremely preterm. Pediatrics 2012;129(5): e1199–204.

[37] Kaczmarek M, Stawinska-Witoszynska B, Krzyzaniak A, Krzywinska-Wiewiorowska M, Siwinska A. Who is at higher risk of hypertension? Socioeconomic status differences in blood pressure among Polish adolescents: a population-based ADOPOLNOR study. Eur J Pediatr 2015;174(11):1461–73.

[38] Gopinath B, Hardy LL, Teber E, Mitchell P. Association between physical activity and blood pressure in prepubertal children. Hypertens Res 2011;34(7):851–5.

[39] Zago AS, Zanesco A. Nitric oxide, cardiovascular disease and physical exercise. Arq Bras Cardiol 2006;87(6):e264–70.

[40] Kelley GA, Kelley KS, Tran ZV. The effects of exercise on resting blood pressure in children and adolescents: a meta-analysis of randomized controlled trials. Prev Cardiol 2003;6(1):8–16.

[41] Kotsis V, Stabouli S, Papakatsika S, Rizos Z, Parati G. Mechanisms of obesity-induced hypertension. Hypertens Res 2010;33(5): 386–93.