Hemoglobin and Hematocrit Levels are Positively Associated with Blood Pressure in Children and Adolescents Aged 10 to 18 Years: The Korea National Health and Nutrition Examination Surveys 2007–2017.

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Abstract

Objective: To investigate investigated the association of hemoglobin (Hb) concentration, hematocrit (Hct) and blood pressure (BP) in children and adolescents.

Methods: The study population consisted of a total 7,950 subjects (4,229 boys, 3,721 girls) aged 10 to 18 years who participated in the Korea National Health and Nutrition Examination Surveys conducted between 2007 and 2017.

Results: The prevalence of hypertension is estimated about 19.19% (21.51% for boys and 16.5% for girls). The prevalence of obesity is estimated about 9.59% (10.5% for boys and 8.6% for girls). Hb and Hct level tended to increase with the degree of obesity and blood pressure. The systolic BP (SBP) and diastolic BP (DBP) have positively correlated with Hb and Hct levels in both sex. In the multiple regression analysis, the Hb and Hct presented positive association with SBP and DBP after adjustment for for age, BMI SDS, alcohol consumption, smoking physical activity, rural residence, household income, diagnosis of T2DM, hypertension, and dyslipidemia.

Conclusion: Hemoglobin and hematocrit levels were positively associated with SBP and DBP, in children and adolescent, aged 10- 18 year.

Introduction

High blood pressure is an important risk factors for cardiovascular disease(1) and the leading causes of global burden of disease(2, 3). High BP in childhood often develops in to hypertension (HTN) in adulthood, as childhood BP predicts adult BP(4–7). It is a growing health problem that is often overlooked(8, 9).

In children younger than 13 years, elevated blood pressure is defined as blood pressure in the 90th percentile or higher for age, height, and sex, and hypertension is defined as blood pressure in the 95th percentile or higher(10). In adolescents 13 years and older, elevated blood pressure is defined as blood pressure of 120 to 129mm Hg systolic and less than 80mm Hg diastolic, and hypertension is defined as blood pressure of 130/80mm Hg or higher(10). HTN in childhood may contribute to premature atherosclerosis and the early development of cardiovascular disease (CVD). Therefore, identifying the prevalence of HTN and determining the potential risk factors in children and adolescents, would be useful for understanding the pathophysiology and improving the treatment and prevention of hypertension. Obesity is knowns as risk factors of childhood HTN (11), pediatric HTN is increasing along with worldwide epidemics of obesity. Chronic kidney disease, sleep disorder is attributed development of HTN (12, 13). Family history of HTN or CVD, male sex, low birth weight, and maternal smoking during pregnancy are additional risk factors, whereas children who were breastfed have a reduced risk of HTN (14, 15). Also, the risk of HTN varies according to race and ethnicity, Hispanic and black children are known to have a greater risk (16).

Abnormalities in blood viscosity have been implicated in a number of cardiovascular disease(17). Hemoglobin (Hb) is the most important determinant of whole blood viscosity(18), and high hemoglobin level would be a potential risk factor to increase the BP. Several studies have reported that Hb concentrations increased in humans with HTN. However, only a limited number of large- population studies have shown an association

between Hb concentration and BP (19–22). Also, population study conducted in childhood was rare. Therefore, the current study investigated the prevalence of HTN and obesity, and the association of Hb, Hct and blood pressure in children and adolescents.

Results

A total 7,950 subject participated in final analysis. Among them, 4,229 were boys (53.19%) and 3,721 were girls. The subjects categorized into 3 groups according to BMI, 3,343 of the boys were normal weight (79.0%), 443 were overweight (10.5%), and 443 was obesity(10.5%). 3,059 of the girls were normal weight (82.2%), 342 were overweight (9.2%), and 320 were obesity (8.6%).

Table 1 presents the clinical characteristics of the study population. The SDS of height and waist circumference were significantly higher for boys than for girls. SBP, DBP, and serum glucose concentrations were higher for boys, and concentrations of TC, TG, HDL-C, and LDL-C were higher for girls. Alcohol drinker and smoker were more common in boys, and physical activity was greater in boys. None of the participants were previously diagnosed with hypertension. However, this studies have showed that 1,526 adolescents have hypertension(910 boys and 616 girls). The prevalence of hypertension in childhood (aged 10–18 year) is about 19.19% (21.5% for boys and 16.5% for girls). In NW group, the prevalence of HTN were about 19.3% for boys, 15.2% for girls. In OW group, the prevalence of HTN were about 26.1% for boys, 18.7% for girls. In OB group, the prevalence of HTN were about 32.9% for boys, 26.8% for girls. Mean Hb (g/dL) were 14.59 ± 1.13 in boys and 13.27 ± 0.94 in girls ($p < 0.001$), mean Hct(%) were 43.40 ± 3.33 in boys and 40.09 ± 2.56 in girls ($p < 0.001$).

Table 1
Clinical characteristics of the study population (n = 7,950).

	Boys	Girls	
	(n = 4,229)	(n = 3,721)	P
Age (years)	14.31 ± 2.51	14.37 ± 2.51	0.319
Height SDS	0.25 ± 1.05	0.19 ± 1.05	0.008
Weight SDS	0.10 ± 1.22	0.06 ± 1.14	0.102
BMI SDS (kg/m^2)	−0.25 ± 1.14	−0.19 ± 1.09	0.656
WC SDS	−0.04 ± 1.29	−0.05 ± 1.19	0.022
SBP (mmHg)	108.79 ± 10.60	104.23 ± 9.32	< 0.001
DBP (mmHg)	66.48 ± 9.45	65.59 ± 8.26	< 0.001
Hemoglobin (g/dL)	14.59 ± 1.13	13.27 ± 0.94	< 0.001
Hematocrit (%)	43.40 ± 3.33	40.09 ± 2.56	< 0.001
Glucose (mg/dL)	90.78 ± 7.70	89.34 ± 8.09	< 0.001
T-C (mg/dL)	155.83 ± 27.11	163.79 ± 26.23	< 0.001
HDL-C (mg/dL)	49.84 ± 9.90	52.22 ± 9.85	< 0.001
TGs (mg/dL)	82.90 ± 47.32	86.50 ± 44.16	0.001
LDL-C (mg/dL)	89.40 ± 23.28	94.27 ± 22.84	< 0.001
Alcohol drinker	1,155 (27.31%)	855 (22.98%)	< 0.001
Smoker	668 (15.80%)	245 (6.58%)	< 0.001
Household income ≤ 1st quartile	460 (10.88%)	410 (11.02%)	0.869
Rural residence	689 (16.29%)	605 (16.26%)	0.992
Physical activity, yes/no	2,474/1,755 (58.50%)	2,052/1,669 (55.15%)	0.003
Diagnosis of hypertension	0	0	> 0.999
Diagnosis of T2DM	2 (0.05%)	1 (0.03%)	> 0.999
Diagnosis of dyslipidemia	0	0	> 0.999

SDS, standard deviation score; WC, waist circumference; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; T-C, total cholesterol; HDL-C, high-density lipoprotein cholesterol; TGs, triglycerides; LDL-C, low-density lipoprotein cholesterol; T2DM, type 2 diabetes mellitus.

Figure 1(a) revealed mean Hb and Hct according to BMI group. Mean Hb and Hct increased significantly in boys, with NW,OW and OB group. The mean Hb (g/dL) were 14.57 ± 1.11 (NW), 14.61 ± 1.16 (OW), 14.78 ± 0.01 (OB) in boys (p < 0.001), and mean Hct (%) were 43.28 ± 3.31(NW), 43.58 ± 3.41(OW), 44.09 ± 3.30 (OB) in boys

($p < 0.001$). The mean Hb (g/dL) were 13.27 ± 0.95(NW), 13.30 ± 0.85(OW), 13.31 ± 0.89 (OB) in girls ($p = 0.587$). Mean Hct (%) were 40.05 ± 2.58 (NW), 40.25 ± 2.44 (OW), 40.34 ± 2.43 (OB) in girls ($p = 0.079$). The mean Hb and Hct level showed a tendency to increased, but there was no significantly difference in girls.

Figure 1(b) revealed mean Hb and Hct level according to hypertension. The mean Hb (g/dL) was significantly higher in subject with hypertension than in whom with normal blood pressure in boys (14.90 ± 1.1 vs 14.44 ± 1.0, respectively ($p < 0.001$)) and girls(13.43 ± 0.93 vs 13.21 ± 0.93, respectively ($p < 0.001$)). Mean Hct (%) was significantly higher in subject with hypertension than in whom with normal blood pressure, too (44.31 ± 3.28 vs 42.95 ± 3.26 in boys ($p < 0.001$), 40.55 ± 2.56 vs 39.91 ± 2.53, in girls ($p < 0.001$).

Mean Hb and Hct according to sex, BMI group and presence of hypertension are shown in Table 2, **Fig. 1(c) and 1(d)**. In boys, when analyzed in all groups according to the BMI, Hb and Hct were significantly higher in cases of HTN than in cases of normal BP ($p < 0.001$). In girls with NW group, Hb and Hct were significantly higher in HTN group than normal BP group ($p < 0.001$, respectively). In girls with OW group, Hb was significantly higher in HTN group ($p < 0.05$), but Hct was not($p = 0.083$). In girls with OB group, Hb and Hct level showed a high tendency in HTN group, but there was no statistically significant difference ($p = 0.295$ and $p = 0.054$, Hb and Hct level in girls with OB, respectively).

Table 2
Hemoglobin and hematocrit levels according to sex, body mass index, and hypertension status.

	Subgroup	**Boys (n = 4,229)**			**Girls (n = 3,721)**		
	n (%)	**NW**	**OW**	**OB**	**NW**	**OW**	**OB**
		3,343 (79.0%)	**443 (10.5%)**	**443 (10.5%)**	**3,059 (82.2%)**	**342 (9.2%)**	**320 (8.6%)**
	No of HTN (%)	648 (19.3%)	116 (26.1%)	146 (32.9%)	466 (15.2%)	64 (18.7%)	86 (26.8%)
Hb (g/dL)	Normal BP	14.46 ± 1.10	14.50 ± 1.07	14.61 ± 1.15	13.24 ± 0.94	13.25 ± 0.82	13.28 ± 0.90
	HTN	15.00 ± 1.05	14.90 ± 1.28	15.13 ± 1.19	13.49 ± 0.96	13.49 ± 0.96	13.40 ± 0.88
Hct (%)	Normal BP	42.97 ± 3.29	43.31 ± 3.28	43.56 ± 3.07	39.96 ± 2.56	40.13 ± 2.34	40.17 ± 2.32
	HTN	44.59 ± 3.05	44.36 ± 3.66	45.18 ± 3.50	40.55 ± 2.66	40.78 ± 2.76	40.80 ± 2.66

Data are presented as the mean ± standard deviation

NW, normal weight; OW, overweight; OB, obese; HTN, hypertension; Hb, hemoglobin; Hct, hematocrit; BP, blood pressure.

HTN was defined as i) systolic blood pressure (SBP) or diastolic blood pressure (DBP) ≥ the 95th percentile value for age, sex, and height or ii) SBP ≥ 130 mmHg or DBP ≥ 80 mmHg

Table 3 presented the correlation between hemoglobin, and hematocrit and blood pressure in all subjects. Hb and Hct level were positively correlated with SBP, DBP in boys and girls. After adjustment for age in all

participants, Hb and Hct were positively correlated with SBP, DBP in both sex, too.

Table 3
Unadjusted and adjusted correlation between hemoglobin or hematocrit and blood pressure in children and adolescents aged 10–18 years (*n* = 7,950).

	No of participants	Unadjusted		Adjusted for age	
		r	*P*	r	*P*
Hb (g/dL)					
SBP,*mmHg*					
Boys	4,229	0.320	< 0.001	0.121	< 0.001
Girls	3,721	0.042	0.010	0.058	< 0.001
DBP, *mmHg*					
Boys	4,229	0.341	< 0.001	0.119	< 0.001
Girls	3,721	0.045	0.006	0.103	< 0.001
Hct (%)					
SBP,*mmHg*					
Boys	4,229	0.345	< 0.001	0.150	< 0.001
Girls	3,721	0.098	< 0.001	0.103	< 0.001
DBP, *mmHg*					
Boys	4,229	0.339	< 0.001	0.114	< 0.001
Girls	3,721	0.088	< 0.001	0.123	< 0.001

Hb, hemoglobin; Hct, hematocrit; SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 4 presented the multiple linear regression between hemoglobin, and hematocrit and blood pressure in boys and girls. The mean SBP and DBP increased with increasing Hb and Hct level in both sex. Model 2 presented statistical significance between hemoglobin, and hematocrit and blood pressure after adjustment for age, BMI SDS, alcohol consumption, smoking physical activity, rural residence, household income, diagnoses of type 2 diabetes mellitus (T2DM), hypertension, and dyslipidemia. In boys, SBP increased by 1.3mmHg with every 1g/dL increase in the Hb concentration. SBP in girls increased by 0.5mmHg with every 1g/dL increase in the Hb concentration. The pattern of DBP were similar to the patterns observed with SBP. DBP increased by 1.1 mmHg in boys, and 0.8 mmHg in girls with every 1g/dL in the Hb concetration. SBP increased by 0.5mmHg with every 1% of hematocrit increase in boys and 0.3mmHg in girls. DBP increased by 0.3mmHg with every 1% of hematocrit increase in both sex.

Table 4
Multiple linear regression of hemoglobin and hematocrit against blood pressure in children and adolescents aged 10–18 years (*n* = 7,950).

Variable	No. of participants	Model 1			Model 2		
		β	SE	*p*	β	SE	*p*
Hb (g/dL)							
SBP,*mmHg*							
Boys	4,229	1.333	0.168	< 0.001	1.341	0.168	< 0.001
Girls	3,721	0.570	0.161	< 0.001	0.553	0.161	< 0.001
DBP, *mmHg*							
Boys	4,229	1.201	0.155	< 0.001	1.196	0.155	< 0.001
Girls	3,721	0.893	0.142	< 0.001	0.889	0.142	< 0.001
Hct(%)							
SBP, *mmHg*							
Boys	4,229	0.559	0.057	< 0.001	0.569	0.057	< 0.001
Girls	3,721	0.366	0.058	< 0.001	0.351	0.058	< 0.001
DBP, *mmHg*							
Boys	4,229	0.390	0.052	< 0.001	0.389	0.053	< 0.001
Girls	3,721	0.389	0.051	< 0.001	0.387	0.051	< 0.001

Hb, hemoglobin; Hct, hematocrit; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI body mass index; SDS, standard deviation score; T2DM, type 2 diabetes mellitus.

Model 1: The statistical significance was determined using multiple linear regression of Hb and Hct versus blood pressure after adjustment for age and BMI SDS.

Model 2: The statistical significance was determined using multiple linear regression of Hb and Hct on blood pressure after adjustment for age, BMI SDS, alcohol consumption, smoking, physical activity, rural residence, household income, diagnosis of T2DM, hypertension, and dyslipidemia.

Discussion

The current study presented the prevalence of obesity and hypertension, and a positive associated between Hb, hematocrit level and blood pressure, in children and adolescent. To our knowledge, this is the first study that investigated the association between hemoglobin and hematocrit level, and systolic and diastolic blood pressure in a large Korean children and adolescents, aged 10–18 years. Our study population was representative of the Korean children and adolescents because the KNHANES is an official, nationwide database that reflects geographic and demographic differences in Korea.

Recently, the prevalence of overweight and obesity has increased rapidly in children and adolescents. Obesity is a multifactorial disease, caused by genetic, biological, environmental, behavioral, psychological factor (23). Childhood obesity leads to adult obesity (24, 25), and increased the risk of cardiovascular disease and mortality in adulthood (26). Severe obesity in children associated with an increased prevalence of cardiometabolic risk factor, including low HDL cholesterol, high SBP and DBP, high TG level, and high glycated hemoglobin level (27).

The prevalence of overweight and obesity was reported more than 10 % in developing countries and even higher (20%) in developed countries (28). Reports on the prevalence of childhood obesity in Korea vary from data to data, but it has increased over time, too. In 2013, the prevalence of overweight and obesity in children age < 20 years was 21.2 in boys and 13.2 in girls, and the prevalence of obesity was 4.8 in boys and 3.1 in girls (28). In our study, the overall prevalence of obesity and overweight was 21% in boys, and 17.8 % in girls, and the prevalence of obesity was 10.5% in boys and 9.2% in girls, aged 10–18 yeas, from 2007 to 2017. Our study did not analyzed the annual prevalence of obesity and overweight. And the difference in prevalence was caused by the age difference between subjects and the method of analysis.

The prevalence of elevated blood pressure and hypertension in children is reported around 6% and 3%, respectively (9, 29). In obese adolescents, the combinded prevalence increases to around 30%(29). Cho H et al reported the prevalence of hypertension increased over time, it was from 6.9% (KNHANES 2007–2009) to 9.0%, (KNHANES 2013–2015) in Korean children and adolescent aged 10–18 year (30). The prevalence of HTN were higher in boys than girls, and increased with severity of obesity. Especially, in obesity group, the prevalence of HTN were higher than average participant, it increased from 14.9% (KNHANES 2007–2009) to 27.7% (KNHANES 2013–2015). In our study, the prevalence of HTN were higher in boys than girls, and increased with severity of obesity, too. However, our study design and analysis of method are different with previous study, the prevalence of HTN was about 19.19 % in overall children and adolescent aged 10–18 year (KNHANES 2007–2017), especially 30.4% in obesity group.

The results of our study showed that the prevalence of obesity and HTN was higher in boys than girls, and the prevalence of HTN was higher in the obesity and overweight group than normal weight group, in both sex. Hb and Hct level tended to increase with the degree of obesity and blood pressure in both sex, but there were sexual divergence. In boys and girls, Hb and Hct increased in hypertension than normal BP. In boys, Hb and Hct level were significantly increased in OB group, than NW and OW group. On the other hand, in girls, Hb and Hct were no difference according to obesity. This indirectly suggest that Hb and Hct are closely related to blood pressure than obesity.

Several studies have investigated the association between Hb concentration, Hct and BP, however, most of study performed in adult (19–22). Previous studies presented that Hb concentration increased in humans with HTN, and it is positively associated with SBP and DBP. Result of our study is in line with the finding of previous studies(19–22, 31–33). Atsma et al reported that Hb level was positively associated with both SBP and DBP in healthy adults whom Dutch voluntary blood donors (18 ~ 70 years of age)(20). They presented that 1.3 mm Hg and 1.8 mm Hg increase in SBP with every 1mmol/L increase in the Hb level for men and women, respectively. And DBP rose 1.4 mm Hg and 1.5 mm Hg increase with every 1mmol/L increase in the Hb level in men and in women, respectively. Lee et al reported that SBP in men with Hb concentration ≥ 13.0 g/dL, and in women with

Hb concentration ≥ 11.0 g/dL, increased by 2.6 mm Hg with every 1mmol/l increase in the Hb concentration. DBP increased by 3.2 mm Hg with every 1mmol/L increase in the Hb concentrationin both men and women in Korean adult population (aged ≥ 20 yeas)(22). In our study, the regression coefficients was relatively lower than the previous study. SBP increased by 1.3mmHg in boys, and 0.5mmHg in girls with every 1g/dL increase in the Hb level, DBP increased by 1.1 mmHg in boys, and 0.8 mmHg in girls with every 1g/dL in the Hb level. In our study, subjects were 10–18 years old, younger than in previous studies, and the unit of Hb was used as g/dL, instead of mmol/L, so the regression coefficient seem so be smaller. It is estimated that the difference in study design, ethnicity and characteristics of the study subject caused the difference in the results.

Göbel et al found significant correlations between mean arterial blood pressure and red blood cell count, Hct, and Hb concentration in healthy subjects. They suggested that Hct plays a role in determining the viscosity of the blood, and that it may be involved as a rheological factor controlling blood pressure (21). Our study did not collect data of red blood cell count, but indicates that Hct and Hb level are involved with blood pressure determination, although the mechanisms for an elevated BP with increasing Hb and Hct level are not entirely known. Previous stud presented higher Hct levels were associated with a higher incidence of hypertension(34). Increased Hct level associated with increased blood viscosity, and that increased viscosity is a determinant of vascular resistance, and it is expected to contribute to blood pressure(35, 36). The fact that polycythemia vera is often associated with cardiovascular disease supported this theory as plausible (37). Moreover, Kawamoto reported that Hb is strongly related to arterial stiffness, which, in turn, increases SBP and DBP(38). Therefore, they suggested a slightly low Hb level was beneficially associated with arterial stiffness in women. Because Hb is a scavenger of nitric oxide (NO), produced in the endothelial cells(39). NO act as vasodilator and to prevent atherosclerosis development and its complications(40). Increased levels of free Hb induce vasoconstriction due to NO scavenging and consequently, an elevation of BP.

The current study has some limitations. First, since our study is a cross sectional study, it is inherently difficult to draw conclusion about any causal relationship between level of Hb or Hct and BP. Second, it is possible to approximate the prevalence of hypertension, but it is difficult to understand the actual prevalence of HTN, because white coat HTN was not excluded. Finally, the cause of the sexual difference in the relationship between Hb or Hct and blood pressure was not fully elucidated. Periodic menstrual bleeding in girls might have influenced the difference of results. However we have no data about pubertal status, diagnosis of anemia and menstrual loss in the present study. Subsequent prospective studies are needed to clarify the mechanisms by which blood pressure increase with increasing Hb and Hct level, and to determine the cause of sexual difference.

In conclusion, Hb and Hct levels were positively associated with SBP and DBP in Korean children and adolescent, aged 10–18 year. Both Hb and Hct levels are involved with blood pressure, and their increase could be a potential risk factor for increasing blood pressure. In particular, obesity could have a synergistic effect that cause high blood pressure. It is important to identify and manage risk factors for cardiovascular disease from childhood and adolescence. Establishing their risk factors and management would be the cornerstone of long – tern health care that influences lifelong qualities. Further research is required to identify and verify the factors that increased blood pressure in children of all ages, including newborn, and different ethnic group.

Material And Methods

Data from the 2007–2017 Korea National Health and Nutrition Examination Survey (KNHANES) were analyzed in this study. The survey has been conducted by the Division of Chronic Disease Surveillance, Korean Centers for Disease Control and Prevention on a 3-year cycle since 1998 to assess the health and nutritional status of the noninstitutionalized civilian population of Korea (41). The KNHANES is a cross-sectional and nationally representative survey with a multistage and stratified probability sampling design. To enhance the statistical power of this analysis, data acquired from the full fourth (2007-2009), fifth (2010-2012), and sixth (2013-2015) cycles and the first year of the seventh cycle (2017) were combined.

A total of 89,630 individuals were included. Of these subjects, 7,950 participants aged 10 to 18 years were included in the preliminary analysis. All subjects and their parents were interviewed at home after providing informed consent and underwent various examinations, including blood sampling (42). Those with incomplete records regarding the physical examination, including anthropometric measurements, blood pressure, and laboratory tests, including the lipid profile, were excluded. Those who had high TGs ≥ 400 mg/dL were also excluded (n = 16). The database is available to the public at the KNHANES website (http://knhabes.cdc.go.kr). The study protocols of the 2007–2017 KNHANES were approved by the institutional review boards of the Korean Centers for Disease Control and Prevention. Informed consent was provided by all KNHANES subjects.

Anthropometric assessments, including height, weight, WC, and systolic and diastolic blood pressure (SBP and DBP, respectively) were performed by a trained expert. Height was measured to the nearest 0.1 cm using an electronic stadiometer (SECA, Germany). Weight was measured to the nearest 0.1 kg with an electronic scale (G-TECH, Korea). WC was measured to the nearest 0.1 cm using a calibrated measuring tape (SECA). SBP and DBP were measured 3 times to the nearest 1 mm Hg using a standard mercury sphygmomanometer. The SD scores (SDS) for height, weight, WC, and BMI were calculated using age- and sex-specific least mean square (LMS) parameters based on the 2017 growth reference values for Korean children and adolescents developed by the Korean Pediatric Society and the Korea Centers for Disease Control and Prevention (43). The subjects were categorized into 3 groups according to BMI: normal weight (NW, BMI was <85th percentile), overweight (OW, BMI was ≥85th percentile and <95th percentile), and obesity (OB,BMI was ≥95th percentile). Hypertension was defined as sex-, age-, and height-specific SBP or DBP equal to or greater than the 95th percentile based on the 2017 Korean reference (43) or SBP ≥130 mmHg or DBP ≥80 mmHg.

Lifestyle-related behaviors, such as alcohol consumption, smoking, household income, and residence, were assessed by means of a questionnaire. Information about alcohol consumption (drinkers vs. nondrinkers) and smoking status (smokers vs. nonsmokers) was collected with a self-administered questionnaire from subjects aged 12 years and older (42). Physical activity was used to divide subjects into two groups (yes or no), and subjects were included in the ‘yes’ group if they performed intense physical activity ≥20 min/day and ≥3 days/week, if they performed moderate physical activity ≥30 min/day and ≥5 days/week, or if they walked ≥30 min/day and ≥5 days/week.

Questionnaires on household income and area of residence (urban vs. rural) were administered by trained interviewers. Diagnosis of HTN, diabetes and dyslipidemia were also included in the questionnaire.

Statistical analyses

R, version 3.5.1 (The R Foundation for Statistical Computing, Austria), was used for statistical analysis. Continuous variables are expressed as mean and SD. Categorical variables are presented as number and the percentages (%). A 2-tailed *t*-test was performed to identify differences in clinical parameters between the boys and girls, whereas categorical variables were compared using the $\chi 2$ test. To determine statistical significance, analysis of variance (ANOVA) was used for hemoglobin and hematocrit according to obesity groups. The Pearson's correlation coefficient analysis was performed to evaluate the correlation between Hb, Hct and blood pressure. Multiple linear regression was performed to investigate the relation between hemoglobin and hematocrit and blood pressure. Probability values less than .05 were considered statistically significant.

Declarations

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The authors have no conflicts of interest to declare.

Author contribution

Dr Jeong drafted the initial manuscript, and reviewed and revised the manuscript.

Dr Lee designed the data collection instruments and reviewed and revised the manuscript.

Dr Shim prepared the original protocol and overall design of the study, collected the data, conducted data management and statistical analyses, and revised the manuscript

Prof Hwang conceptualized and designed the study, coordinated and supervised data collection, and critically reviewed the manuscript for important intellectual content.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

References

1. Kannel WB, Dawber TR, Kagan A, Revotskie N, Stokes J, 3rd. Factors of risk in the development of coronary heart disease–six year follow-up experience. The Framingham Study. Annals of internal medicine. 1961;55:33-50.
2. Ezzati M, Lopez AD, Rodgers A, Vander Hoorn S, Murray CJ. Selected major risk factors and global and regional burden of disease. Lancet (London, England). 2002;360(9343):1347-60.
3. Lawes CM, Vander Hoorn S, Rodgers A. Global burden of blood-pressure-related disease, 2001. Lancet (London, England). 2008;371(9623):1513-8.
4. Lauer RM, Clarke WR. Childhood risk factors for high adult blood pressure: the Muscatine Study. Pediatrics. 1989;84(4):633-41.

5. Sun SS, Grave GD, Siervogel RM, Pickoff AA, Arslanian SS, Daniels SR. Systolic blood pressure in childhood predicts hypertension and metabolic syndrome later in life. Pediatrics. 2007;119(2):237-46.
6. 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.
7. Falkner B, Gidding SS, Portman R, Rosner B. Blood pressure variability and classification of prehypertension and hypertension in adolescence. Pediatrics. 2008;122(2):238-42.
8. Riley M, Hernandez AK, Kuznia AL. High Blood Pressure in Children and Adolescents. American family physician. 2018;98(8):486-94.
9. Hansen ML, Gunn PW, Kaelber DC. Underdiagnosis of hypertension in children and adolescents. Jama. 2007;298(8):874-9.
10. Flynn JT, Kaelber DC, Baker-Smith CM, Blowey D, Carroll AE, Daniels SR, et al. Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents. Pediatrics. 2017;140(3).
11. Falkner B, Gidding SS, Ramirez-Garnica G, Wiltrout SA, West D, Rappaport EB. The relationship of body mass index and blood pressure in primary care pediatric patients. The Journal of pediatrics. 2006;148(2):195-200.
12. Archbold KH, Vasquez MM, Goodwin JL, Quan SF. Effects of sleep patterns and obesity on increases in blood pressure in a 5-year period: report from the Tucson Children's Assessment of Sleep Apnea Study. The Journal of pediatrics. 2012;161(1):26-30.
13. Flynn JT, Mitsnefes M, Pierce C, Cole SR, Parekh RS, Furth SL, et al. Blood pressure in children with chronic kidney disease: a report from the Chronic Kidney Disease in Children study. Hypertension (Dallas, Tex : 1979). 2008;52(4):631-7.
14. Lawlor DA, Najman JM, Sterne J, Williams GM, Ebrahim S, Davey Smith G. Associations of parental, birth, and early life characteristics with systolic blood pressure at 5 years of age: findings from the Mater-University study of pregnancy and its outcomes. Circulation. 2004;110(16):2417-23.
15. Martin RM, Ness AR, Gunnell D, Emmett P, Davey Smith G. Does breast-feeding in infancy lower blood pressure in childhood? The Avon Longitudinal Study of Parents and Children (ALSPAC). Circulation. 2004;109(10):1259-66.
16. Brady TM, Fivush B, Parekh RS, Flynn JT. Racial differences among children with primary hypertension. Pediatrics. 2010;126(5):931-7.
17. Wells R. Syndromes of hyperviscosity. The New England journal of medicine. 1970;283(4):183-6.
18. de Simone G, Devereux RB, Chien S, Alderman MH, Atlas SA, Laragh JH. Relation of blood viscosity to demographic and physiologic variables and to cardiovascular risk factors in apparently normal adults. Circulation. 1990;81(1):107-17.
19. Shimizu Y, Nakazato M, Sekita T, Kadota K, Arima K, Yamasaki H, et al. Association between the hemoglobin levels and hypertension in relation to the BMI status in a rural Japanese population: the Nagasaki Islands Study. Internal medicine (Tokyo, Japan). 2014;53(5):435-40.
20. Atsma F, Veldhuizen I, de Kort W, van Kraaij M, Pasker-de Jong P, Deinum J. Hemoglobin level is positively associated with blood pressure in a large cohort of healthy individuals. Hypertension (Dallas, Tex : 1979).

2012;60(4):936-41.

21. Göbel BO, Schulte-Göbel A, Weisser B, Glänzer K, Vetter H, Düsing R. Arterial blood pressure. Correlation with erythrocyte count, hematocrit, and hemoglobin concentration. American journal of hypertension. 1991;4(1 Pt 1):14-9.
22. Lee SG, Rim JH, Kim JH. Association of hemoglobin levels with blood pressure and hypertension in a large population-based study: the Korea National Health and Nutrition Examination Surveys 2008-2011. Clinica chimica acta; international journal of clinical chemistry. 2015;438:12-8.
23. Lee EY, Yoon KH. Epidemic obesity in children and adolescents: risk factors and prevention. Frontiers of medicine. 2018;12(6):658-66.
24. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. Jama. 2014;311(8):806-14.
25. Venn AJ, Thomson RJ, Schmidt MD, Cleland VJ, Curry BA, Gennat HC, et al. Overweight and obesity from childhood to adulthood: a follow-up of participants in the 1985 Australian Schools Health and Fitness Survey. The Medical journal of Australia. 2007;186(9):458-60.
26. Twig G, Yaniv G, Levine H, Leiba A, Goldberger N, Derazne E, et al. Body-Mass Index in 2.3 Million Adolescents and Cardiovascular Death in Adulthood. The New England journal of medicine. 2016;374(25):2430-40.
27. Skinner AC, Perrin EM, Moss LA, Skelton JA. Cardiometabolic Risks and Severity of Obesity in Children and Young Adults. The New England journal of medicine. 2015;373(14):1307-17.
28. 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. Lancet (London, England). 2014;384(9945):766-81.
29. McNiece KL, Poffenbarger TS, Turner JL, Franco KD, Sorof JM, Portman RJ. Prevalence of hypertension and pre-hypertension among adolescents. The Journal of pediatrics. 2007;150(6):640-4, 4.e1.
30. Cho H, Kim JH. Secular trends in hypertension and elevated blood pressure among Korean children and adolescents in the Korea National Health and Nutrition Examination Survey 2007-2015. Journal of clinical hypertension (Greenwich, Conn). 2020;22(4):590-7.
31. Yan X, Zheng S, Ji J, Zuo J, Qian Y. A18078 The hemoglobin was associated with blood pressure in the Chinese community-dwelling cohort. 2018;36:e345.
32. Jamshidi-Naeini Y, Bavil AK, Egal A, Oldewage-Theron W. Hemoglobin and ferritin concentrations are positively associated with blood pressure and hypertension risk in older adults: a retrospective cross-sectional study, Sharpeville, South Africa. Asia Pacific journal of clinical nutrition. 2019;28(3):533-43.
33. Chen XT, Yang S, Yang YM, Zhao HL, Chen YC, Zhao XH, et al. Exploring the relationship of peripheral total bilirubin, red blood cell, and hemoglobin with blood pressure during childhood and adolescence. Jornal de pediatria. 2018;94(5):532-8.
34. Jae SY, Kurl S, Laukkanen JA, Heffernan KS, Choo J, Choi YH, et al. Higher blood hematocrit predicts hypertension in men. Journal of hypertension. 2014;32(2):245-50.
35. Taco-Vasquez ED, Barrera F, Serrano-Duenas M, Jimenez E, Rocuts A, Riveros Perez E. Association between Blood Viscosity and Cardiovascular Risk Factors in Patients with Arterial Hypertension in a High

Altitude Setting. Cureus. 2019;11(1):e3925.

36. Lowe GD, Lee AJ, Rumley A, Price JF, Fowkes FG. Blood viscosity and risk of cardiovascular events: the Edinburgh Artery Study. British journal of haematology. 1997;96(1):168-73.
37. Nand S, Orfei E. Pulmonary hypertension in polycythemia vera. American journal of hematology. 1994;47(3):242-4.
38. Kawamoto R, Tabara Y, Kohara K, Miki T, Kusunoki T, Katoh T, et al. A slightly low hemoglobin level is beneficially associated with arterial stiffness in Japanese community-dwelling women. Clinical and experimental hypertension (New York, NY : 1993). 2012;34(2):92-8.
39. Cabrales P, Han G, Nacharaju P, Friedman AJ, Friedman JM. Reversal of hemoglobin-induced vasoconstriction with sustained release of nitric oxide. American journal of physiology Heart and circulatory physiology. 2011;300(1):H49-56.
40. Bian K, Doursout MF, Murad F. Vascular system: role of nitric oxide in cardiovascular diseases. Journal of clinical hypertension (Greenwich, Conn). 2008;10(4):304-10.
41. Kweon S, Kim Y, Jang MJ, Kim Y, Kim K, Choi S, et al. Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). International journal of epidemiology. 2014;43(1):69-77.
42. Park HK, Shim YS. Distribution of Tri-Ponderal Mass Index and its Relation to Body Mass Index in Children and Adolescents Aged 10 to 20 Years. The Journal of clinical endocrinology and metabolism. 2020;105(3):e826-34.
43. Kim JH, Yun S, Hwang SS, Shim JO, Chae HW, Lee YJ, et al. The 2017 Korean National Growth Charts for children and adolescents: development, improvement, and prospects. Korean journal of pediatrics. 2018;61(5):135-49.

Figures

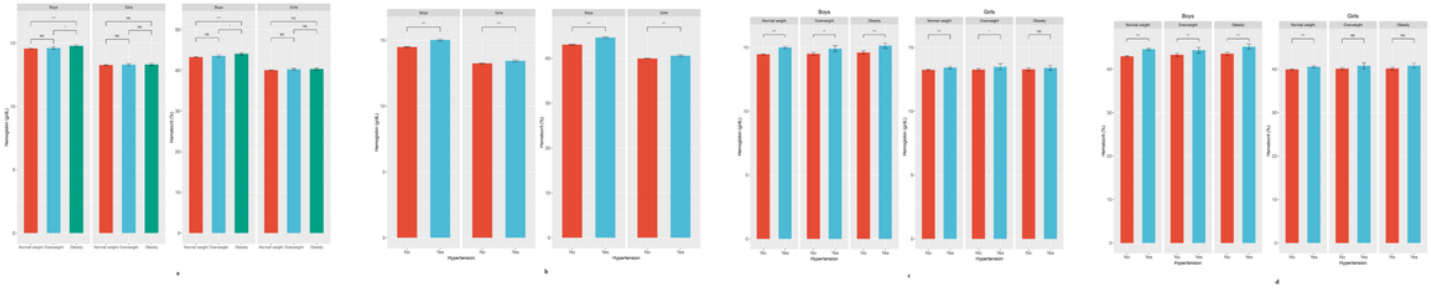

Figure 1

a) Hemoglobin (Hb) and hematocrit (Hct) levels according to obesity status in boys and girls. b) Hb and Hct levels according to hypertension status in boys and girls. c) Hb concentration according to obesity and hypertension status in boys and girls. d) Hct level according to obesity and hypertension status in boys and girls. *, $p < 0.05$; **, $p < 0.005$; ***, $p < 0.001$; NS, $p > 0.05$