Article

Biological Research for Nursing
1-9

DOI: 10.1177/1099800420941074
journals.sagepub.com/home/brn
SAGE

Obesity-Related Parameters Are Associated With Blood Pressure in Palestinian Children

Moath Abu Ejheisheh, RN[1], María Correa-Rodríguez, RN, PhD[1,2], Ángel Fernández-Aparicio, RN[1,2], Ahmad Batran, RN, PhD[3], María José Membrive-Jiménez, RN[4], and Jacqueline Schmidt-RioValle, RN, PhD[1,2]

Abstract

Hypertension has been established as a common health condition in young people. Most studies have focused on the impact of body mass index (BMI), but the relationships between body composition parameters and blood pressure in Palestinian children has not previously been investigated. We aimed to analyze the prevalence of overweight/obesity and elevated blood pressure/hypertension and investigate the associations among obesity-related parameters, including anthropometric and body composition markers and blood pressure levels in a population of 971 Palestinian school children (50% girls; mean age 10.3 $\pm$ 1.1 years). Anthropometric measurements including height, waist circumference (WC), hip circumference (HC), waist-to-hip ratio (WHR), and waist to height ratio (WHtR) were assessed. A body composition analyzer was used to measure body weight, fat mass, and fat-free mass. Blood pressure including systolic (SBP), diastolic (DBP) and mean arterial pressure (MAP) were measured using a Dinamap vital signs monitor. The prevalence of overweight/obesity was 25.3% in the girls and 23.1% in the boys. 26.3% of the children had elevated systolic blood pressure, or systolic hypertension; whereas 23.4% had elevated diastolic blood pressure, or diastolic hypertension. All obesity-related variables, with the exception of WHR and WHtR, showed statistical differences among the normotension, elevated blood pressure and hypertension groups for systolic and diastolic blood pressure ($p < 0.05$). Children with elevated blood pressure or hypertension had significantly higher weight, BMI, WC, HC, fat mass, and fat-free mass values compared to participants with normotension, supporting the direct association between obesity and hypertension in this population. Weight-reduction interventions are essential for reducing the prevalence of childhood hypertension in Palestinian children.

Keywords

blood pressure, body composition, obesity, hypertension, anthropometry, children, Palestinian

Childhood obesity is considered to be a global public health problem because it has reached epidemic levels in both developed and developing countries (World Health Organization, 2019). The alarming rate of childhood obesity has resulted in an increase in the rates of obesity-related co-morbidities, including hypertension, type 2 diabetes mellitus, and metabolic syndrome, which are serious and potentially life-threatening health conditions (Jiang et al., 2016; Pantalone et al., 2017). Moreover, obesity in childhood tracks strongly into adulthood because overweight children are more prone to becoming overweight adults (Biro & Wien, 2010). In fact, it has been estimated that almost half of overweight adults were overweight as children (Deshmukh-Taskar et al., 2006). The etiology of obesity is multifactorial and the mechanisms underlying childhood obesity have still not been fully elucidated. Nevertheless, it is well established that obesity is the consequence of interactions among a complex set of factors, including a positive energy balance, physical inactivity, and a genetic predisposition for weight gain (Hruby & Hu, 2015; Xu & Xue, 2016).

Body mass index (BMI) has been shown to provide a reasonable estimate of adiposity in the healthy pediatric population (Pietrobelli et al., 1998). The Centers for Disease Control and Prevention (CDC) published BMI reference standards for children (CDC, 2014). Thus, overweight is defined as a BMI between the 85th and 95th percentiles for age and sex, and obesity as a BMI at or greater than the 95th percentile for age and sex.

[1] Department of Nursing, Health Sciences Faculty, University of Granada (UGR), Granada, Spain
[2] CTS-436 Aspectos psicosociales y Transculturales de la Salud y la Enfermedad, Granada, Spain
[3] Faculty of Nursing, Arab American University, Jenin, Palestine
[4] University Hospital of Ceuta, Institute of Health Management, Ceuta, Spain

Corresponding Author:
María Correa-Rodríguez, RN, PhD, Department of Nursing, Health Sciences Faculty, University of Granada (UGR), Avenida de la Ilustración 60, 18016 Granada, Spain.
Email: macoro@ugr.es

However, BMI may slightly overestimate fatness in children who are short or who have a relatively high muscle mass, and may underestimate adiposity in children with reduced muscle mass due to a sedentary lifestyle (Vanderwall et al., 2017).

The prevalence of obesity varies according to racial, ethnic, and socioeconomic factors. In Palestine, according to the Ministry of Health (2018), chronic diseases such as hypertension, type 2 diabetes mellitus, and metabolic syndrome associated with increased obesity account for 50% of deaths. Al-Lahham et al. (2019) reported that the prevalence of obesity among Palestinian children increased from 3% to 6% over a 5-year period, in comparison to the global rise from 1% to 7% over 41 years, suggesting that childhood obesity is a major public health problem in this country.

Due to the global obesity epidemic, hypertension has now been established as one of the most common health conditions in youth (Flynn, 2013). Data from the National Health and Nutrition Examination Survey (NHANES) revealed that 14% of adolescents from 12 to 19 years of age were suffering prehypertension or hypertension (The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents, 2004). Interestingly, Al-Agha & Mahjoub (2018) showed that an elevated BMI is associated with increased diastolic and systolic blood pressure among obese children and adolescents in the western region of Saudi Arabia. Nevertheless, the evidence available on the relationship between obesity and hypertension in Palestinian children is limited. Most studies have focused on the impact of BMI or anthropometric measurements on blood pressure, but these studies provide no data on body composition. Thus, the potential relationships among body composition parameters and blood pressure values in a specific cohort of Palestinian children have not been analyzed previously. Measurements of body composition, including fat mass and fat-free mass in addition to anthropometric markers, would provide data to further the understanding of the potential associations between obesity and hypertension in children.

In this context, the aim of this study was to analyze the prevalence of overweight/obesity and elevated blood pressure/hypertension and investigate the potential associations among obesity-related parameters including weight, BMI, waist circumference, hip circumference (HP), waist-to-hip ratio (WHR), waist to height ratio (WHtR), fat mass and fat-free mass, and blood pressure levels in a large population of Palestinian children.

Methods

Study Design and Participants

A cross-sectional study was conducted in a sample consisted of Palestinian school children recruited from eight public education centers in Jenin, Hebron, Nablus and Tulkarem. These cities were selected based on convenience and the public education centers were selected randomly for inclusion. An informational meeting was held, when parents and children were informed of the study purpose and procedures. They received an informed consent form, which included a detailed description of the study. At this meeting, screening for inclusion criteria and informed consent were completed. The inclusion criteria required the participants to be healthy and to not suffer from any type of endocrine dysfunction (thyroid, adrenal, or pancreas), physical disorder, or infectious process. All students who did not meet these criteria were not candidates to participate in the study. At the end of the informal meeting, a total of 971 children aged 9–12 years (486 males and 485 females) were authorized by their parents or legal guardians to participate in this study. Ethical approval for this study was granted by the Ethics and Research Committee of Arab American University (Palestine). Permission has been obtained from Ministry of Education in Palestine. It was performed according to the International Code of Medical Ethics established by the World Medical Association and the Declaration of Helsinki. Written informed consent was obtained for all participants.

After the informal meeting, another meeting was scheduled to collect data with instructions. Measurements were taken in the morning after a 12 hours fast with no consumption of food or beverages, as well as a 24 hours abstention from exercise, under resting conditions. Days before the measurements, children, parents, or legal guardians were informed of these restrictions. Before their body composition was measured, the children were also asked about compliance with these conditions.

Anthropometric Measurements

The anthropometric measurements including height, WC, HC, WHR, and WHtR were included. A Harpenden stadiometer (Harpenden 602 VR, Holtain, Wales, UK®) was used for height measurements. Each participant was asked to stand erect with his/her back, buttocks, and heels in continuous contact with the vertical height rod of the stadiometer and head oriented in the Frankfurt plane. The horizontal head piece was then placed on top of the participant's head to measure his/her height. Height was measured twice without shoes to the nearest 0.5 cm. Waist circumference was measured twice with a Seca automatic roll-up measuring metal tape (precision of 1 mm) using the horizontal plane midway between the lowest rib and the upper border of the iliac crest at the end of a normal inspiration/expiration. Hip circumference was measured twice at the maximum extension of the buttocks as viewed from the right side. The averages of the two values for each measurement were used in the analysis. BMI was calculated as body weight in kilograms divided by the square height in meters, and overweight and obesity were defined by the international standards of Cole et al. (2000), corresponded to values higher than the 85th and 95th percentiles, respectively, for BMI-forage and sex. The anthropometric measurements recorded by a standard procedure ensuring inter observer reliability and were measured by the same anthropometrist according to the International Society for the Advancement of Kinanthropometry (ISAK; Marfell-Jones et al., 2011).

Body Composition Measurements

A body composition analyzer (TANITA BC-418MA®) was used to measure body weight (kg), fat mass (kg), and fat-free mass (kg) to the nearest 0.1 kg. This was done twice when participants were dressed in light indoor clothing without shoes and the average was used for analysis. The measurement room provides for privacy and was at a comfortable temperature for the participants.

Blood Pressure

Blood pressure including systolic (SBP), diastolic (DBP), mean arterial pressure (MAP) were measured using a Dinamap vital signs monitor (model BP 8800, Critikon, Inc., Tampa, FL.), following the recommendations of the European Heart Society (on the right arm in a semi-flexed position at heart level, with participants in a supine position and after 10 min of rest). Hypertension in children was defined as a systolic or diastolic blood pressure (BP) value $\geq$ 95th percentile. Blood pressure between the 90th and 95th percentile in childhood was designated "elevated blood pressure" (Flynn et al., 2017).

Statistical Analysis

We described numerical variables using $\pm$ standard deviation, while qualitative or nominal variables were described using frequencies and percentages. The Kolmogorov–Smirnov test was used to evaluate whether the distribution of continuous variables was normal, showing that all the examined variables were normally distributed. The independent two-sample *t*-test was used to compare the variables between girls and boys. Linear regression analysis were conducted to determine the associations among blood pressure measurements and anthropometric and body composition variables. In the overall population, regression analyses were adjusted by age and gender and in the stratified analysis by sex, linear regressions were adjusted by age. Comparisons of body composition variables across categories of blood pressure (normotension, elevated blood pressure and hypertension) were based on a one-way ANOVA after adjusted by age and sex in the overall population and adjusted only by age in the stratified analysis. SPSS Statistics version 21.0 (SPSS. Chicago, IL, USA) was used for all the analyses and p values < 0.05 were considered to be statistically significant.

Results

The clinical characteristics of the sample are presented in Table 1. The mean age of the study population was 10.2 $\pm$ 1.1 years. The prevalence of overweight/obesity was 25.3% in girls and 23.1% in boys, and 63.9% of the participants were of normal weight. Note that 26.3% of children had elevated systolic blood pressure or systolic hypertension (10.5% had elevated systolic blood pressure and 15.8% had systolic hypertension), whereas 23.4% had elevated diastolic blood pressure or diastolic hypertension (10.6% had elevated diastolic blood pressure and 12.8% had diastolic hypertension). Significant differences were observed between boys and girls with respect to height, BMI, WC, WHR, fat mass, fat-free mass, SBP, DBP, and MBP ($p <$ 0.05). The boys presented significantly higher values of height, WC, WHR, fat-free mass, SBP, DBP, and MBP than the girls (p < 0.05). In contrast, the girls had significantly higher BMI and fat mass values ($p < 0.05$).

Table 1. Descriptive Characteristics of Study Participants by Gender.

	Girls (n = 486) Mean (SD)	Boys (n = 485) Mean (SD)	Overall (n = 971) Mean (SD)	*p* value*
Age	10.1 (1.1)	10.4 (1.0)	10.2 (1.1)	<0.001
Height	138.3 (9.1)	140.8 (10.7)	139.5 (10.0)	<0.001
Weight	35.6 (9.4)	36.1 (11.2)	35.9 (10.3)	0.414
BMI	18.5 (3.7)	18.0 (3.9)	18.2 (3.8)	0.047
WC	63.4 (8.2)	64.9 (9.8)	64.2 (9.0)	0.009
HC	75.1 (8.9)	73.9 (10.8)	74.5 (9.9)	0.071
WHR	0.8 (0.0)	0.8 (0.0)	0.8 (0.0)	<0.001
WHtR	0.4 (0.0)	0.4 (0.0)	0.4 (0.0)	0.424
Fat mass	8.5 (5.1)	6.8 (6.0)	7.6 (5.6)	<0.001
Fat free mass	27.1 (5.1)	29.3 (6.5)	28.2 (5.9)	<0.001
SBP	111.7 (11.6)	113.6 (9.5)	112.7 (10.6)	0.005
DBP	68.3 (9.9)	70.2 (8.7)	69.3 (9.4)	0.002
MBP	82.8 (9.6)	84.7 (8.0)	83.7 (8.9)	0.001

Note. SD, standard deviation; BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist-to-hip ratio; WHtR, waist to height ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure. **p* values are based on the comparison between boys and girls.

The association analyses between the blood pressure measurements and obesity-related parameters in the overall population and by sex are shown in Table 2. In the whole population, MBP and SBP were significantly associated with all anthropometric and body composition variables ($p < 0.05$). Note that all obesity-related markers were associated with DBP except WHR, and WHtR. In girls, the tendency is similar, MBP, SBP, and DBP were significantly related to all anthropometric and body composition variables, except for WHR, which was not related to MBP and DBP. In boys, however, weight, BMI, WC, fat mass, and free mass were significantly associated with blood pressure levels.

Table 3 shows the anthropometric and body composition measurements for the SBP classification groups (normotension, elevated blood pressure and hypertension), for the total sample and stratified by sex. In the total sample, all obesity-related variables, with the exception of WHR and WHtR, showed statistically significant differences between the three groups ($p <$ 0.05). Children with hypertension had significantly higher weight, BMI, WC, HC, fat mass and fat-free mass values compared to participants with normotension ($p < 0.05$). In girls, the values of weight, WC, HC, WHtR, and fat free mass were significantly higher in the hypertension group compared to the normotension group. In boys, fat mass values were significantly higher in participants with systolic hypertension compared to participants with normotension (6.6 $\pm$ 5.3 versus 7.2 $\pm$ 7.5; $p =$ 0.012). Note that boys with normal SBP values presented significantly higher weight ($p = 0.012$), HC ($p = 0.046$), and fat free mass ($p = 0.006$) values.

Obesity-related measurements for the DBP classification groups (normotension, elevated blood pressure and hypertension), for the total sample and stratified by sex are presented in Table 4. In the total sample, participants with diastolic

Table 2. Association Between Blood Pressure Measurements and Anthropometric and Body Composition.

	Girls (n = 486)						Boys (n = 485)						Overall population (n = 971)					
	MBP		SBP		DBP		MBP		SBP		DBP		MBP		SBP		DBP	
	β (95% CI)	*p* value	β (95% CI)	*p* value	β (95% CI)	*p* value	β (95% CI)	*p* value	β (95% CI)	*p* value	β (95% CI)	*p* value	β (95% CI)	*p* value	β (95% CI)	*p* value	β (95% CI)	*p* value
Weight	0.187 (0.090, 0.285)	<0.001	0.258 (0.140, 0.375)	<0.001	0.152 (0.051, 0.254)	0.003	0.123 (0.051, 0.196)	0.001	0.165 (0.079, 0.252)	<0.001	0.103 (0.023, 0.182)	0.011	0.144 (0.084, 0.203	<0.001	0.199 (0.127, 0.270)	<0.001	0.116 (0.053, 0.180)	<0.001
BMI	0.289 (0.054, 0.525)	0.016	0.343 (0.059, 0.627)	0.018	0.263 (0.019, 0.507)	0.035	0.271 (0.086, 0.455)	0.004	0.334 (0.115, 0.553)	0.003	0.239 (0.039, 0.439)	0.019	0.276 (0.128, 0.424)	<0.001	0.335 (0.158, 0.513)	<0.001	0.246 (0.089, 0.403)	0.002
WC	0.216 (0.111, 0.320)	<0.001	0.309 (0.184, 0.434)	<0.001	0.169 (0.060, 0.278)	0.002	0,073 (−0.002, 0.149	0.056	0.126 (0.037, 0.215)	0.006	0.047 (−0.034, 0.129)	0.256	0,129 (0.067, 0.192)	<0.001	0.199 (0.124, 0.274)	<0.001	0.094 (0.028, 0.161)	0.005
HC	0.171 (0.072, 0.271)	0.001	0.219 (0.099, 0.338)	<0.001	0.148 (0.045, .251)	0.005	0.054 (−0.022, 0.130)	0.164	0.078 (−0.012, 0.168)	0.090	0.042 (−0.040, 0.124)	0.318	0,094 (0.033, 0.155)	0.003	0.129 (0.056, 0.202)	0.001	0.076 (0.012, 0.141)	0.021
WHR	9.956 (−1.745, 21.657)	0.095	18.416 (4.340, 32.491)	0.010	5.726 (−6.419, 17.871)	0.355	3.284 (−4.851, 11.418)	0.428	9.100 (−0.527, 18.727)	0.064	0.376 (−8.434, 9.185)	0.933	6,919 (0.112, 13.725)	0.046	13.457 (5.331, 21.584)	0.001	3.650 (−3.544, 10.843)	0.320
WHtR	22.014 (5.103, 38.924)	0.011	30.829 (10.455, 51.203)	0.003	17.606 (0.042, 35.171)	0.049	5.929 (−5.807, 17.665)	0.321	12.088 (−1.815, 25.990)	0.088	2.850 (−9.862, 15.562)	0.660	12,613 (2.655, 22.570)	0.013	19.823 (7.922, 31.725)	0.001	9.008 (−1.518, 19.533)	0.093
Fat mass	0.263 (0.094, 0.432)	0.002	0.342 (0.138, 0.546)	0.001	0.223 (0.048, 0.399)	0.013	0.133 (0.012, 0.254)	0.031	0.225 (0.082, 0.367)	0.002	0.087 (−0.044, 0.218)	0.193	0,186 (0.085, 0.287)	<0.001	0.273 (0.152, 0.394)	<0.001	0.142 (0.035, 0.250)	0.009
Fat free mass	0.430 (0.236, 0.624)	<0.001	0.643 (0.411, 0.874	<0.001	0.323 (0.121, 0.526)	0.002	0.267 (0.128, 0.406)	<0.001	0.334 (0.169, 0.500)	<0.001	0.233 (0.082, 0.385)	0.003	0.309 (0.194, 0.425)	<0.001	0.438 (0.301, 0.576)	<0.001	0.245 (0.122, 0.367)	<0.001

Note. MBP, mean blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist-to-hip ratio; WHtR, waist to height ratio. Data were adjusted by age and gender in the overall population and only by age in the stratified analysis by sex.

Table 3. Anthropometric and Body Composition Variables Across SBP Categories.

	Girls (n = 486)				Boys (n = 485)				Overall (n = 971)			
	Normotension (n = 368)	Elevated blood pressure (n = 43)	Hypertension (n = 75)		Normotension (n = 348)	Elevated blood pressure (n = 59)	Hypertension (n = 78)		Normotension (n = 716)	Elevated blood pressure (n = 102)	Hypertension (n = 153)	
	Mean (SD)	Mean (SD)	Mean (SD)	*p* value	Mean (SD)	Mean (SD)	Mean (SD)	*p* value	Mean (SD)	Mean (SD)	Mean (SD)	*p* value
Weight	35.4 (9.4)	35.2 (7.7)	36.7 (10.3)	0.002	36.5 (10.5)	33.7 (9.8)	36.4 (14.4)	0.012	35.9 (10.0)	34.3 (9.0)	36.6 (12.5)	<0.001
BMI	18.4 (3.7)	18.4 (3.2)	18.7 (3.5)	0.252	17.9 (3.7)	18.0 (3.8)	18.2 (4.8)	0.088	18.2 (3.7)	18.2 (3.6)	18.5 (4.2)	0.039
WC	62.9 (8.3)	63.8 (7.5)	65.7 (8.0)	0.001	65.1 (9.3)	63.2 (9.8)	65.2 (11.8)	0.387	64.0 (8.8)	63.5 (8.8)	65.5 (10.1)	0.002
HC	74.8 (8.7)	74.7 (8.7)	76.8 (9.7)	0.002	74.4 (10.6)	71.3 (10.5)	73.8 (12.0)	0.046	74.6 (9.6)	72.7 (9.9)	75.3 (11.0)	<0.001
WHR	0.8 (0.0)	0.8 (0.0)	0.8 (0.0)	0.224	0.8 (0.0)	0.8 (0.1)	0.8 (0.1)	0.236	0.8 (0.0)	0.8 (0.0)	0.8 (0.1)	0.937
WHtR	0.4 (0.0)	0.4 (0.0)	0.4 (0.0)	0.048	0.4 (0.0)	0.4 (0.0)	0.4 (0.0)	0.991	0.4 (0.0)	0.4 (0.0)	0.4 (0.0)	0.245
Fat mass	8.3 (5.0)	8.35 (4.2)	9.1 (5.9)	0.055	6.6 (5.3)	7.6 (7.5)	7.2 (7.5)	0.012	7.5 (5.2)	7.9 (6.3)	8.1 (6.8)	0.003
Fat free mass	27.0 (5.1)	27.0 (4.0)	27.7 (5.6)	<0.001	29.8 (6.3)	27.1 (5.7)	29.2 (7.7)	0.006	28.3 (5.9)	27.1 (5.0)	28.5 (6.7)	<0.001

Note. Data are shown as mean ± SD. Data were adjusted by age and gender in the overall population and only by age in the stratified analysis by sex. BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist-to-hip ratio; WHtR, waist to height ratio. **p* values are based on the comparison between normotension and elevated blood pressure/hypertension.

Table 4. Anthropometric and Body Composition Variables Across DBP Classification.

	Girls (n = 486)				Boys (n = 485)				Overall sample (n = 971)			
	Normotension (n = 379)	Elevated blood pressure (n = 30)	Hypertension (n = 77)		Normotension (n = 365)	Elevated blood pressure (n = 73)	Hypertension (n = 47)		Normotension (n = 744)	Elevated blood pressure (n = 103)	Hypertension (n = 124)	
	Mean (SD)	Mean (SD)	Mean (SD)	*p* value	Mean (SD)	Mean (SD)	Mean (SD)	*p* value	Mean (SD)	Mean (SD)	Mean (SD)	*p* value
Weight	35.4 (9.3)	34.6 (8.7)	37.1 (10.1)	0.005	35.9 (10.7)	36.4 (12.0)	37.2 (13.5)	0.026	35.7 (10.0)	35.9 (11.1)	37.1 (11.5)	<0.001
BMI	18.3 (3.3)	18.6 (3.3)	19.2 (5.1)	0.017	17.8 (3.8)	18.5 (4.0)	18.5 (4.5)	0.048	18.0 (3.5)	18.6 (3.8)	18.9 (4.9)	0.001
WC	63.0 (8.3)	63.4 (6.9)	65.6 (8.1)	0.003	64.8 (9.7)	65.4 (10.3)	65.0 (9.7)	0.439	63.9 (9.0)	64.8 (9.4)	65.4 (8.7)	0.006
HC	74.7 (8.7)	74.7 (7.4)	77.1 (9.9)	0.003	73.9 (11.0)	74.0 (9.7)	74.2 (11.2)	0.129	74.3 (9.9)	74.2 (9.1)	76.0 (10.4)	<0.001
WHR	0.8 (0.0)	0.8 (0.0)	0.8 (0.0)	0.743	0.8 (0.0)	0.8 (0.1)	0.8 (0.0)	0.522	0.8 (0.0)	0.8 (0.1)	0.8 (0.0)	0.322
WHtR	0.4 (0.0)	0.4 (0.0)	0.4 (0.0)	0.055	0.4 (0.0)	0.4 (0.0)	0.4 (0.0)	0.422	0.4 (0.0)	0.4 (0.0)	0.4 (0.0)	0.078
Fat mass	8.3 (5.0)	8.4 (4.7)	9.3 (5.9)	0.048	6.7 (5.9)	7.1 (6.1)	7.4 (6.9)	0.323	7.5 (5.5)	7.4 (5.7)	8.6 (6.4)	0.014
Fat free mass	27.1 (5.0)	26.1 (4.4)	27.7 (5.6)	0.001	29.3 (6.3)	29.3 (6.9)	29.8 (7.6)	0.009	28.2 (5.8)	28.4 (6.4)	28.5 (6.5)	<0.001

Note. Data are shown as mean ± SD. Data were adjusted by age and gender in the overall population and only by age in the stratified analysis by sex. BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist-to-hip ratio; WHtR, waist to height ratio. **p* values are based on the comparison between normotension and elevated blood pressure/hypertension.

hypertension had significantly higher values for obesity-related parameters, with the exception of WHR and WHtR, compared to the normotension group ($p < 0.05$). This tendency was similar in girls, and there were also significant differences in all anthropometric outcomes, with the exception of WHR and WHtR, between the groups ($p < 0.05$). For boys, the weight, BMI, and fat free mass values were significantly higher in participants with diastolic hypertension compared to normotension participants ($p < 0.05$).

Discussion

Based on a large sample of 971 Palestinian children, we found that all obesity-related parameters, with the exception of WHR and WHtR, presented statistical differences between the normotension, elevated blood pressure, and hypertension groups for systolic and diastolic blood pressure. Thus, children with elevated blood pressure or hypertension have significantly higher weight, BMI, WC, HC, fat mass, and fat-free mass values compared to participants with normotension, supporting the direct association between high values for obesity related-parameters and high blood pressure values in children from Palestine. These findings are clinically relevant since obesity and hypertension are both linked to a high risk of cardiovascular disease, increasing related morbidity and mortality in adulthood (Brady et al., 2016; Morrison et al., 2007).

Hypertension is a growing health issue in children, mainly due to its association with obesity (Orlando et al., 2018). Similar to our findings, previous studies have also evidenced an association between anthropometric parameters and blood pressure values in childhood (Brady, 2017). A retrospective study conducted on subjects from 3 to 17 years of age in the United States also reported a statistically significant association between increased BMI percentile and increased blood pressure percentile, with the risk of incident hypertension associated primarily with obesity (Parker et al., 2016). Likewise, a study on a cohort of Portuguese children reported that WC is itself a risk factor predictor for hypertension in children and adolescents (Burgos et al., 2013), and other research from China also showed that a child's BMI, WC, and WHtR were positively associated with their SBP and DBP, showing that obese children were 3 to 6 times more likely to suffer hypertension (Zhao et al., 2017). Additionally, an elevated BMI was associated with increased diastolic and systolic blood pressure in 300 obese children in the western region of Saudi Arabia (Al-Agha & Mahjoub, 2018). However, this is the first study to evaluate the link between body composition parameters and blood pressure in a cohort of Palestinian children. The positive relationship between obesity-related markers, including fat mass and blood pressure levels in this cohort, evidences the need to develop effective strategies to prevent overweight and obesity in this population.

Hypertension in children will easily become hypertension in adults, and this is an important cardiovascular risk factor which increases the risk of cardiovascular disease (Urbina et al., 2019). Interestingly, a recent study found that obesity-related hypertension in children was related to increased cardiovascular morbidity and mortality (Wühl, 2019). Thus, interventions aimed at weight reduction that include lifestyle modification with a multidisciplinary approach are essential for reducing childhood hypertension. With regard to the potential mechanisms underlying the link between obesity and elevated blood pressure, it has been proposed that the sympathetic nervous system, the renin–angiotensin–aldosterone system, the amount of intra-abdominal and intra-vascular fat, and sodium retention leading to increased renal reabsorption, might all play an important role in the pathogenesis of obesity-related hypertension (Brady, 2017).

On the other hand, in our study, 26.3% of children had elevated systolic blood pressure or systolic hypertension, whereas 23.4% had elevated diastolic blood pressure or diastolic hypertension. In a cross-sectional study conducted on a large population of young people 6 to 17 years of age from Southern California, the prevalence of elevated blood pressure and hypertension were 31.4% and 2.1%, respectively (Koebnick et al., 2013). Moreover, children 3 to 17 years of age from Nigeria, the prevalence of hypertension and elevated blood pressure was found to be 3.5% and 2.5%, respectively (Okpokowuruk et al., 2017). Interestingly, data obtained from a prospective national survey in China showed that the overall prevalence of elevated blood pressure and hypertension were 6.0% and 10.6%, respectively (Fan et al., 2019). The differences in ethnicity and age range between the various studies may account for the disparity in the reported prevalence. For this reason, further studies on children from Palestine are required in order to verify and compare our results.

The prevalence of overweight/ obesity in our study was 25.3% in girls and 23.1% in boys. A previous cross-sectional study conducted among school-age Palestinian children reported that the prevalence of overweight and obesity was approximately 14.5% and 15.7%, respectively, which supports an accelerated increase in the prevalence of overweight/obesity (Al-Lahham et al., 2019). Similarly, findings from marginalized Palestinian schools in the West Bank showed that the 34% of adolescents were overweight or obese (85th percentile or over; Amer et al., 2019) and a systematic review of childhood obesity in the Middle East and North Africa (MENA) region concluded that the obesity rate in children and adolescents is rising rapidly (Farrag et al., 2017). Thus, the countries in the MENA region should endorse strategies and programs to prevent and manage this problem in an effective way. Family-based lifestyle changes, including decreasing total caloric intake, increasing physical activity and decreasing sedentary time, have been proposed as the cornerstone of weight management in children (Kumar & Kelly, 2017), and should be implemented in Palestinian children. Interestingly, a recent study on Palestinian children found that living in the city, maternal and paternal BMI, WC, modes of transport, and chocolate and sweet intake, were significantly associated with the BMI of children (Al-Lahham et al., 2019). Those authors concluded that the increased prevalence of childhood obesity might be due to the rapid urbanization and transition from conventional to western lifestyles. Furthermore, the fluctuations and instability of Palestinian societal and political life could affect the nutrition status of children, since access to health services is complicated and people are exposed to food insecurity in some regions of Palestine (Mataria et al., 2009; Qlalweh et al., 2012).

One limitation of this study is its cross-sectional design, which cannot infer causality. In addition, since our study population comprised a well-characterized cohort of Palestinian children, this may limit the generalizability of the results to other populations. Its strengths are that, to the best of our knowledge, this is the first study to examine the relationship between obesity-related parameters, including body composition parameters and blood pressure levels, in a cohort of Palestinian children. Additionally, body composition measurements were performed using a body composition analyzer (TANITA BC-418MA). Bioelectrical impedance analysis (BIA) has been postulated as a valuable tool for measuring body composition, and is a significantly more cost-effective method than dual-energy X-ray absorptiometry (DXA; Beeson et al., 2010).

Conclusion

The prevalence of overweight/obesity was 25.3% in girls and 23.1% in boys, and 26.3% of Palestinian children have elevated systolic blood pressure/hypertension whereas 23.4% have elevated diastolic blood pressure/hypertension. Palestinian children with elevated blood pressure or hypertension have significantly higher weight, BMI, WC, HC, fat mass, and fat-free mass values than the participants with normotension, supporting a direct association between high values of obesity related-parameters and high blood pressure values. Our results therefore highlight the need for a serious focus on obesity in Palestinian children and reveal the need for community-based programs to manage this health problem. Weight reduction interventions are essential to reduce the prevalence of related disorders, such as childhood hypertension, and, for this reason, the prevention of childhood obesity should be a national public health priority in Palestine.

Acknowledgments

This manuscript is part of the PhD thesis developed by Moath Abu Ejheisheh, included in the Official PhD Program of Clinical Medicine and Public Health at the University of Granada, Spain.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

María Correa-Rodríguez https://orcid.org/0000-0001-9165-4349

References

Al-Agha, A. E., & Mahjoub, A. O. (2018). Impact of body mass index on high blood pressure among obese children in the western region of Saudi Arabia. *Saudi Medical Journal*, *39*(1), 45–51. https://doi.org/10.15537/smj.2018.1.20942

Al-Lahham, S., Jaradat, N., Altamimi, M., Anabtawi, O., Irshid, A., Alqub, M., Dwikat, M., Nafaa, F., Badran, L., Mohareb, R., Haji, R., Aqqad, T., Jayyab, S., Ghosh, B. A., Taher, R., & Al Zabadi, H. (2019). Prevalence of underweight, overweight and obesity among Palestinian school-age children and the associated risk factors: a cross sectional study. *BMC Pediatrics*, *19*(483). https://doi.org/10.1186/s12887-019-1842-7

Amer, S., Kateeb, E., Hassan, A., & Musa, F. (2019). Dietary habits, energy drink consumption, obesity, and physical activity in marginalised Palestinian schools in the West Bank: A cross-sectional study. *The Lancet*, *393*(S13). https://doi.org/10.1016/S0140-6736(19)30599-9

Beeson, W. L., Batech, M., Schultz, E., Salto, L., Firek, A., Deleon, M., Balcazar, H., & Cordero-Macintyre, Z. (2010). Comparison of body composition by bioelectrical impedance analysis and dual-energy X-ray absorptiometry in hispanic diabetics. *International Journal of Body Composition Research*, *8*(2), 45–50.

Biro, F. M., & Wien, M. (2010). Childhood obesity and adult morbidities. *American Journal of Clinical Nutrition*, *91*(5), 1499S–1505S. https://doi.org/10.3945/ajcn.2010.28701B

Brady, T. M. (2017). Obesity-related hypertension in children. *Frontiers in Pediatrics*, *5*, 197. https://doi.org/10.3389/fped.2017.00197

Brady, T. M., Appel, L. J., Holmes, K. W., Fivush, B., & Miller, E. R. (2016). Association between adiposity and left ventricular mass in children with hypertension. *Journal of Clinical Hypertension*, *18*(7), 625–633. https://doi.org/10.1111/jch.12717

Burgos, M. S., Burgos, L. T., Camargo, M. D., Franke, S. I. R., Prá, D., da silva, A. M. V., Borges, T. S., Todendi, P. F., Reckziegel, M. B., & Reuter, C. P. (2013). Associação entre medidas antropométricas e fatores de risco cardiovascular em crianças e adolescentes. *Arquivos Brasileiros de Cardiologia*, *101*(4), 288–296. https://doi.org/10.5935/abc.20130169

Centers for Disease Control and Prevention (CDC). Division of Nutrition, Physical Activity, and Obesity, National Center for Chronic Disease Prevention and Health Promotion. (2014). Using BMI-for-age as a Screening Tool—BMI for Age Training Course. Retrieved April 19, 2020, from https://www.cdc.gov/nccdphp/dnpao/growthcharts/training/bmiage/page2.html

Cole, T. J., Bellizzi, M. C., Flegal, K. M., & Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ (Clinical Research Ed.)*, *320*(7244), 1240–1243. https://doi.org/10.1136/BMJ.320.7244.1240

Deshmukh-Taskar, P., Nicklas, T. A., Morales, M., Yang, S. J., Zakeri, I., & Berenson, G. S. (2006). Tracking of overweight status from childhood to young adulthood: The Bogalusa Heart Study. *European Journal of Clinical Nutrition*, *60*(1), 48–57. https://doi.org/10.1038/sj.ejcn.1602266

Fan, Z., Liao, Z., Zong, X., & Zhang, S. (2019). Differences in prevalence of prehypertension and hypertension in children and adolescents in the eastern, central and western regions of China from 1991-2011 and the associated risk factors. *PLoS ONE*, *14*(1). https://doi.org/10.1371/journal.pone.0210591

Farrag, N. S., Cheskin, L. J., & Farag, M. K. (2017). A systematic review of childhood obesity in the Middle East and North Africa (MENA) region: Health impact and management. *Advances in Pediatric Research*, *4*, 6. https://doi.org/10.12715/apr.2017.4.6

Flynn, J. (2013). The changing face of pediatric hypertension in the era of the childhood obesity epidemic. *Pediatric Nephrology*, *28*(7), 1059–1166. https://doi.org/10.1007/s00467-012-2344-0

Flynn, J. T., Kaelber, D. C., Baker-Smith, C. M., Blowey, D., Carroll, A. E., Daniels, S. R., de Ferranti, S. D., Dionne, J. M., Falkner, B.,, Flinn, S. K., Gidding, S. S., Goodwin, C., Leu, M. G., Powers, M. E., Rea, C., Samuels, J., Simasek, M., Thaker, V. V., Urbina, E. M., & Okechukwu, K. (2017). Clinical practice guideline for screening and management of high blood pressure in children and adolescents. *Pediatrics*, *140*(3), e20171904. https://doi.org/10.1542/peds.2017-1904

Hruby, A., & Hu, F. B. (2015). The epidemiology of obesity: A big picture. *PharmacoEconomics*, *33*(7), 673–689. https://doi.org/10.1007/s40273-014-0243-x

Jiang, S. Z., Lu, W., Zong, X. F., Ruan, H. Y., & Liu, Y. (2016). Obesity and hypertension. *Experimental and Therapeutic Medicine*, *12*(4), 2395–2399. https://doi.org/10.3892/etm.2016.3667

Koebnick, C., Black, M. H., Wu, J., Martinez, M. P., Smith, N., Kuizon, B. D., Jacobsen, S. J., & Reynolds, K. (2013). The prevalence of primary pediatric prehypertension and hypertension in a real-world managed care system. *Journal of Clinical Hypertension*, *15*(11), 784–792. https://doi.org/10.1111/jch.12173

Kumar, S., & Kelly, A. S. (2017). Review of childhood obesity: From epidemiology, etiology, and comorbidities to clinical assessment and treatment. *Mayo Clinic Proceedings*, *92*(2), 251–265. https://doi.org/10.1016/j.mayocp.2016.09.017

Marfell-Jones, M., Olds, T., & Stewart, A. (2011). *International standards for anthropometric assessment*. International Society for the Advancement of Kinanthropometry. https://doi.org/10.1152/japplphysiol.00187.2013

Mataria, A., Khatib, R., Donaldson, C., Bossert, T., Hunter, D. J., Alsayed, F., & Moatti, J. P. (2009). The health-care system: An assessment and reform agenda. *The Lancet*, *373*(9670), 1207–1217. https://doi.org/10.1016/S0140-6736(09)60111-2

Morrison, J. A., Friedman, L. A., & Gray-McGuire, C. (2007). Metabolic syndrome in childhood predicts adult cardiovascular disease 25 years later: The Princeton lipid research clinics follow-up study. *Pediatrics*, *120*(2), 340–345. https://doi.org/10.1542/peds.2006-1699

Okpokowuruk, F. S., Akpan, M. U., & Ikpeme, E. E. (2017). Prevalence of hypertension and prehypertension among children and adolescents in a semi-urban area of Uyo Metropolis, Nigeria. *Pan African Medical Journal*, *28*, 303. https://doi.org/10.11604/pamj.2017.28.303.14396

Orlando, A., Cazzaniga, E., Giussani, M., Palestini, P., & Genovesi, S. (2018). Hypertension in children: Role of obesity, simple carbohydrates, and uric acid. *Frontiers in Public Health*, *6*, 129. https://doi.org/10.3389/fpubh.2018.00129

Pantalone, K. M., Hobbs, T. M., Chagin, K. M., Kong, S. X., Wells, B. J., Kattan, M. W., Bouchard, J., Sakurada, B., Milinovich, A., Weng, W., Bauman, J., Misra-Hebert, A. D., Zimmerman, R. S., & Burguera, B. (2017). Prevalence and recognition of obesity and its associated comorbidities: Cross-sectional analysis of electronic health record data from a large US integrated health system. *BMJ Open*, *7*(11). https://doi.org/10.1136/bmjopen-2017-017583

Parker, E. D., Sinaiko, A. R., Kharbanda, E. O., Margolis, K. L., Daley, M. F., Trower, N. K., Sherwood, N. E., Greenspan, L. C., Lo, J. C., Magid, D. J, & O'Connor, P. J. (2016). Change in weight status and development of hypertension. *Pediatrics*, *137*(3). https://doi.org/10.1542/peds.2015-1662

Pietrobelli, A., Faith, M. S., Allison, D. B., Gallagher, D., Chiumello, G., & Heymsfield, S. B. (1998). Body mass index as a measure of adiposity among children and adolescents: A validation study. *Journal of Pediatrics*, *132*(2), 204–210. https://doi.org/10.1016/S0022-3476(98)70433-0

Qlalweh, K., Duraidi, M., & Brønnum-Hansen, H. (2012). Health expectancy in the occupied Palestinian territory: Estimates from the Gaza Strip and the West Bank: Based on surveys from 2006 to 2010. *BMJ Open*, *2*(6). https://doi.org/10.1136/bmjopen-2012-001572

State of Palestine. Ministry of Health. (2018). *Health Annual Report*. Palestine.

The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents. National Heart, Lung, and Blood Institute (NHLBI). (2004). *Pediatrics*, *114*, 555–576. https://www.nhlbi.nih.gov/health-topics/fourth-report-on-diagnosis-evaluation-treatment-high-blood-pressure-in-children-and-adolescents

Urbina, E. M., Khoury, P. R., Bazzano, L., Burns, T. L., Daniels, S., Dwyer, T., Hu, T., Jacobs, D. R Jr., Juonala, M., Prineas, R., Raitakari, O., Steinberger, J., Venn, A., Woo, J. G., & Sinaiko, A. (2019). Relation of blood pressure in childhood to self-reported hypertension in adulthood. *Hypertension*, *73*(6), 1224–1230. https://doi.org/10.1161/HYPERTENSIONAHA.118.12334

Vanderwall, C., Randall Clark, R., Eickhoff, J., & Carrel, A. L. (2017). BMI is a poor predictor of adiposity in young overweight and obese children. *BMC Pediatrics*, *17*(1). https://doi.org/10.1186/s12887-017-0891-z

World Health Organization. (2019). Facts and figures on childhood obesity.

Wühl, E. (2019). Hypertension in childhood obesity. *Acta Paediatrica, International Journal of Paediatrics*, *108*, 37–43. https://doi.org/10.1111/apa.14551

Xu, S., & Xue, Y. (2016). Pediatric obesity: Causes, symptoms, prevention and treatment (review). *Experimental and Therapeutic Medicine*, *11*(1), 15–20. https://doi.org/10.3892/etm.2015.2853

Zhao, Y., Wang, L., Xue, B., & Wang, Y. (2017). Associations between general and central obesity and hypertension among children: The Childhood Obesity Study in China Mega-Cities. *Scientific Reports*, *7*(1). https://doi.org/10.1038/s41598-017-16819-y