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Impact of Body Mass Index Changes on Development of Hypertension in Preparatory School Students: A Cross Sectional Study Based on Anthropometric Measurements

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Abstract Assessing nutritional status using body mass index (BMI) measurements and body compositions evaluation could be simple clinical reliable tools and indicators of adolescent health. On the other hand, hypertension becomes a serious public health problem affecting both children and adolescents. This study aimed at evaluating the association of body composition alterations and development of blood pressure changes among adolescents in Taif governorate, Saudi Arabia. A cross sectional survey design was adopted in which 701 children (aged 12-15) years in Taif city were drawn and randomly selected from the preparatory schools. Measurement of systolic/diastolic blood pressure and comprehensive assessment of anthropometric parameters were done for all participants including weight, height, waist and hip circumferences in addition to triceps, biceps, subscapular and supra-iliac skinfold thickness. Body mass index (BMI), percentage body fat, waist: hip, total body fat and lean body mass were also calculated. In our study, 29.8% of participants were underweight, 9.8% were overweight, 4% were obese and 56.3% showed normal BMI. 6.7% of the participants suffered from hypotension while 6.1% had hypertension. Interestingly, BMI was significantly associated with a greater prevalence of hypertension (normal weight 1.91%, overweight 2.90%, and obesity 10 %). In conclusion, our study sheds the light on the importance of using BMI and anthropometric measures in evaluating the unhealthy weight status of adolescent school students as early predictors of hypertension development. Saudi Anthropometric measurements are comparable to international standards. The future life style changes (sedentary life vs. exercise and food type) impact the development of diabetes mellitus and metabolic syndrome in the Saudi society.

Keywords: *anthropometry, obesity, overweight, hypertension, underweight*

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1. Introduction

Children are the future of any nation. School age is the active growing phase of childhood. Physical growth of children is widely recognized as one of the most sensitive and reliable indicators of health and nutritional status in human populations [1]. Adolescence (12-15 years old) is a transitional phase between childhood and adulthood characterized by marked acceleration in growth [2,3]. A large number of adolescents from South and South-east Asian countries suffer from chronic malnutrition and anemia which affect their development. In most developing countries, nutrition initiatives have focused on children and women neglecting adolescents, especially boys [4].

Assessment of nutritional status using anthropometric measurements provides information on the growth and body compositions. Obtaining and analyzing these data give us invaluable information for categorizing children as

underweight, normal, and overweight/obese. Childhood nutrition is an extremely significant social issue that requires a comprehensive and integrated management [5,6].

Recommended measurements for assessing nutritional status in school-aged children and adolescents are body mass index (BMI)-for-age and height-for-age [7]. Low BMI-for-age is classified as thinness while high BMI-for-age as overweight and obesity, and low height-for-age as stunting [7]. The proportion of individual fat mass over body weight defines body fat percentage. A higher body fat percentage might indicate a higher level of cardiovascular risk [8]. Body fat percentage has been used along with BMI to evaluate human health risks such as cardiovascular risk in clinical practice [9,10]. Percentage body fat is considered high when exceeding 25% (for pubertal boys), > 30% (pre-pubertal children) or > 35% (for pubertal girls) [11]. Conversely, a low percentage body fat of 6-10% in boys and 12-15% in girls can adversely affect metabolism and health. It may also indicate diseases, starvation or an eating disorder such as anorexia nervosa [12]. As obesity has become a serious public health problem affecting both adults and children, it is important to monitor the body compositions of children in order to safeguard against future diseases. Obesity in childhood and adolescence is most often associated with type 2 diabetes mellitus and impaired glucose tolerance that were shown to be quite high in both obese children (25%) and obese adolescents (21%) [13,14].

Recently, pediatric hypertension was observed as a health problem of increasing interest and importance. Asymptomatic children with elevated blood pressure can develop target organ damage and are at an increased risk of cardiovascular diseases in adulthood. On the other hand, there is less information about screening and management of obesity and hypertension in children than in adults. Thus, early detection, proper evaluation, and appropriate management of hypertension at an early age are important for the prevention or restriction of diseases related to hypertension [15].

Studies on body compositions in children and adolescents as well as blood pressure in the Arab Gulf countries are few and limited in their indices. Weight, height, mid-arm circumference and skinfold thickness are usually used to determine body compositions of school children in these countries [16-18]. Findings indicated an increase in body fat with age, especially in girls. However, none of these studies have used body fat equations to determine the fat content in school children. Our study is pioneering in shedding light on the magnitude of that health problem in Saudi Arabia (having a high world ranking in hyperlipidemia and metabolic syndrome) using multiple anthropometric measurements.

2. Subjects and Methods

2.1. Study Objectives

The aim of this study is to assess body compositions through anthropometric equations and to evaluate the nutritional status and its relation to blood pressure levels among preparatory school students in Taif city, Saudi Arabia. Ethical committee approval was gained before starting the study. All steps were done in light of standard rules and regulations and according to the declaration of Helsinki.

2.2. Subjects and Methods

A cross-sectional study design was adopted and conducted in Taif city, Kingdom of Saudi Arabia during the period of January to May 2016. Six governmental male preparatory schools participated in our study from which preparatory stage students were randomly selected. A two-stage random sampling technique was used. In the first stage, six schools from a list of schools registered in the Ministry of Education in Taif city were selected randomly. In the second stage, all students from these schools (Regardless of their socioeconomic status; aged 12-15 years old) were invited to participate in the study. Students' participation was optional. The first author of this article is an experienced medical professor and clinical anatomist who visited the schools, investigated the students, did all the anthropometric measurements and performed the statistical analyses. The sample size for our study was calculated using Epi info software version 7 with a power of 80 %, confidence interval level 95 %, sample errors of 5 %. The total students at the selected schools were obtained from the regional education directorate official data. The estimated sample size was calculated with an extra 20% was added to compensate the possible non-response or refusal rate, and then the final sample was 701 participants. Assessments were done during the school period on students who agreed to participate and presented an informed consent signed from parents/guardians (n=701). Assessments were performed by trained personnel using calibrated equipment. Measuring BMI and skinfold thickness were done following the international norms (Average of three measurements).

2.2.1. Anthropometric Measurements

1. Weight measured to the nearest 0.1 Kg without shoes and with light clothes.

2. Height measured to the nearest 0.5 cm without shoes.

3. Waist circumference measured midway between the lower border of the costal margin and the iliac crest.

4. Hip circumference measured around the largeest buttock extension.

5. Blood pressure measurement was performed using a mercury column sphygmomanometer where three measurements were obtained with a minimum interval of two minutes [19] and according to the recommendations of the national institute of health. Blood pressure readings [20] were categorized as follows: (Normal blood pressure =120/80 mmHg; Pre-hypertension =139/89 mmHg; Hypertension =140/90mmHg). From the above anthropometric measurements, the following body indices were calculated:

Body mass index (BMI) = weight (Kg)/ height (m^2). According to the WHO, BMI was classified into the following 4 categories [21], (Underweight: BMI <18.5 Kg/ m^2 & Normal: BMI for values in the range of 18.5 – 25kg/m^2 & Overweight: BMI between 25 - 29.9 kg/m^2 & Obese: BMI=30 Kg/ m^2 or more). ***Waist/ hip ratio***: Waist

circumference/ hip circumference was measured and the ideal Waist/ hip ratio for men is considered 0.90 or less while 1.0 + or more was considered at risk [22]. ***Skin fold thickness*** was done following a quick non-invasive method that requires a minimal number of tools to calculate the total body fat. Measurement of the skinfold site was done from the right side of each participant and in accordance with the procedures described by Lohman et al. [23]. Skinfold thickness (using skinfold caliper) was measured at ***Biceps*** (Over the mid-point of biceps muscle), ***Triceps*** (Over the mid-point of triceps muscle), ***Subscapular*** (At an oblique line at the inferior angle of the scapula) and Supra-***iliac site*** **(**above the iliac crest). **Body composition measurements:** Human body is composed of two main compartments, fat-free mass or lean body mass (LBM) and body fat mass (BFM). In assessment, male percentage of body fat (% BF) between 5 to 10 is considered low, 11 to 25 is considered as a healthy range, 26 to 30 percent is the overweight range while a percentage over 30 is classified as obese. According to the the previously reported formula [24], body fat was measured as follows**:** Child body fat % = (1.51 x BMI) – (0.70 x Age) – (3.6 x sex) + 1.4 while Adult body fat % = (1.20 x BMI) + (0.23 x Age) – (10.8 sex) – 5.4. The lean body mass (LBM) or the fat free mass (FFM) is recorded based on the formula of Gibson [25] as follows: Total body fat (FM) = (percentage body fat/100) x body weight (kg) while Lean body mass = body weight (kg) - body FM (kg). Analysis was done using the Statistical Package for the Social Science (SPSS) version 13.0, considering $p < 0.05$ as significant. Throughout this research, we adhered to the Saudi ethical guidelines for epidemiologic studies; and the study protocol was approved by the Institutional Review Boards of the Regional Directorate for health Affairs.

3. Results

A total of seven hundred and one (n = 701) preparatory school students aged 12-15 years were evaluated in this study. The mean age of all participants was 14.03 ± 0.73 years. Means ±standard deviation (Mean±SD) of the anthropometric measurements and body composition parameters are shown in Table 1 and Figure 1. The mean value of the body weight for the studied subjects was 45.72 ±15.37 kg. Students' weights exhibited highly significant correlation ($p<0.001$) with BMI (r=.924), body fat (r=0.924) and total body fat (r=0.912). Correlations were non-significant with the age (r=0.041). The mean value of height for all subjects was 151.87±10.11 (Table 1). Height was highly significantly correlated ($p<0.001$) with weight of students (r=0.593) and lean body mass (r=0.772) and low significantly correlated with the waist to hip ratio (r=0.037) (Table 2.). The mean value of the BMI among the study group was 19.30 ± 5.37 kg/m^2 (Table 1). BMI was significantly correlated ($p<0.001$) with body measurements, while highest significant correlation of BMI was observed with weight (r=0.924), body fat % (r=0.998) and total body fat (r=0.954). The least correlation of BMI was observed with age (r=0.077). Based on BMI scale, categorization of the study group revealed that 29.8% of students were underweight, 56.3% were normal, 9.8% were overweight while 4% were obese (Table 3).

Table 1. Detailed anthropometric measurements of the study group

Anthropometric parameter	(Mean ±SD)
Age (year)	14.03±0.73
Weight (kg)	45.72 ±15.37
Height (cm)	152.87 ±10.11
Waist circumference (cm)	70.41±11.89
Hip circumference (cm)	83.84 ±12.13
Systolic blood pressure (mmHg)	111.75 ±15.67
Diastolic blood pressure (mmHg)	68.70 ±11.96
Biceps skinfold (mm)	10.41 ±6.58
Triceps skinfold (mm)	14.60 ±8.33
Subscapular skinfold (mm)	13.05 ±8.70
Supra-iliac skinfold (mm)	16.69 ±11.63
BMI (kg/m^2)	19.30 ±5.37
Waist/hip ratio	0.839 ±0.05
Body fat percentage	17.12 ±8.09
Lean body mass (kg)	36.75 ±8.37
Total body fat (kg)	8.97 ±8.51

Table 2. Correlation coefficient (r) for the studied variables (Anthropometric parameters)

Variable	Age	Wt (kg)	Ht (cm)	waist circ. (cm)	Hip circ. (cm)	SBP (mmHg)	DBP (mmHg)	Biceps (mm)	Triceps (mm)	Subscapular (mm)	Suprailiac (mm)	BMI	Waist/hip ratio	Body Fat %	lean Body Mass	Total Body Fat
Age (year)	1.0	.041	-.070	.098**	.051	.111**	.152**	.271**	.242**	.139**	.119**	.077*	.132**	.014	.050	.024
Wt (kg)	.041	1.0	.593**	.860**	.888**	.374**	.238**	.663**	.703**	.764**	.754**	.924**	.235**	.924**	.909**	.912**
Ht (cm)	-.070	.593**	1.0	.397**	.479**	.291**	.204**	.176**	.192**	.242**	.241**	.257**	-.037	.262**	.772**	.312**
Waist circ. (cm)	.098**	.860**	.397**	1.0	.931**	.340**	.190**	.785**	.800**	.878**	.869**	.844**	.507**	.841**	.817**	.749**
Hip circ. (cm)	.051	.888**	.479**	.931**	1.0	.347**	.202**	.723**	.746**	.816**	.812**	.839**	.163**	.838**	.861**	.757**
SBP (mmHg)	.111**	.374**	.291**	.340**	.347**	1.0	.557**	.270**	.274**	.307**	.303**	.313**	.112**	.307**	.392**	.289**
DBP (mmHg)	.152**	.238**	.204**	.190**	.202**	.557**	1.0	.216**	.181**	.172**	.196**	.194**	.050	.185**	.253**	.181**
Biceps (mm)	.271**	.663**	.176**	.785**	.723**	.270**	.216**	1.0	.879**	.832**	.822**	.714**	.410**	.699**	.606**	.600**
Triceps (mm)	.242**	.703**	.192**	.800**	.746**	.274**	.181**	.879**	1.0	.876**	.861**	.753**	.398**	.740**	.636**	.644**
Subscapular (mm)	.139**	.764**	.242**	.878**	.816**	.307**	.172**	.832**	.876**	1.0	.906**	.801**	.439**	.795**	.691**	.699**
Supra-iliac (mm)	.119**	.754**	.241**	.869**	.812**	.303**	.196**	.822**	.861**	.906**	1.0	.793**	.432**	.787**	.701**	.671**
BMI (kg/m2)	.077*	.924**	.257**	.844**	.839**	.313**	.194**	.714**	.753**	.801**	.793**	1.0	.301**	.998**	.725**	.954**
Waist hip ratio	.132**	.235**	-.037	.507**	.163**	.112**	.050	.410**	.398**	.439**	.432**	.301**	1.0	.294**	.196**	.232**
Body Fat %	.014	.924**	.262**	.841**	.838**	.307**	.185**	.699**	.740**	.795**	.787**	.998**	.294**	1.0	.724**	.955**
Lean Body Mass (kg)	.050	.909**	.772**	.817**	.861**	.392**	.253**	.606**	.636**	.691**	.701**	.725**	.196**	.724**	1.0	.657**
Total Body Fat(kg)	.024	.912**	.312**	.749**	.757**	.289**	.181**	.600**	.644**	.699**	.671**	.954**	.232**	.955**	.657**	1.0

Wt, Weight; Ht, Height; Circ., Circumference; BMI, Body Mass Index; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure *Significant Correlation at level $P < 0.05$ ** Highly significant Correlation at level $P < 0.001$.

Table 3. Distribution of the studied sample according body mass index and blood pressure changes

	Number of Students	Percentage
Body Mass Index		
Underweight	395	29.8%
Normal	209	56.3%
Overweight	69	9.8%
Obese	28	4%
Blood Pressure		
Hypotension	190	6.7%
Normal	388	87.2%
Hypertension	31	6.1%

Table 4. Percentage of blood pressure within the distributed studied sample

BMI Scale	No. of students	Blood pressure changes		
		Hypotension	Normal (PB)	Hypertension
Underweight	209	6.58%	92.91%	0.51%
Normal	395	2.87%	95.22%	1.91%
Overweight	69	1.45%	95.65%	2.90%
Obese	28	0.00%	89.29%	10.71%

Table 5. The prevalence of underweight, overweight and obesity among preparatory school students in different regions

Country	Age	Underweight	Normal	Overweight	Obese	Reference
Al Madina, KSA	12-15	16%	29.6%	6.3%	10.8%	(32)
Riyadh, KSA	12-20	9.1%	56.5%	13.8%	20.5%	(33)
Jeddah, KSA	9-21	25.7%	46.1%	14%	14%	(34)
Jazan, KSA	12-15	29.4%	63,2%	6.6%	1%	(38)
Kuwait	11-14	6.7%	30.2%	25.5%	37.6%	(35)
Gaza, Palestine	12-15	4.9%	76.8	12.8%	5.5%	(36)
Australia	13-18	4.4%	69.6%	20%	6.1%	(37)

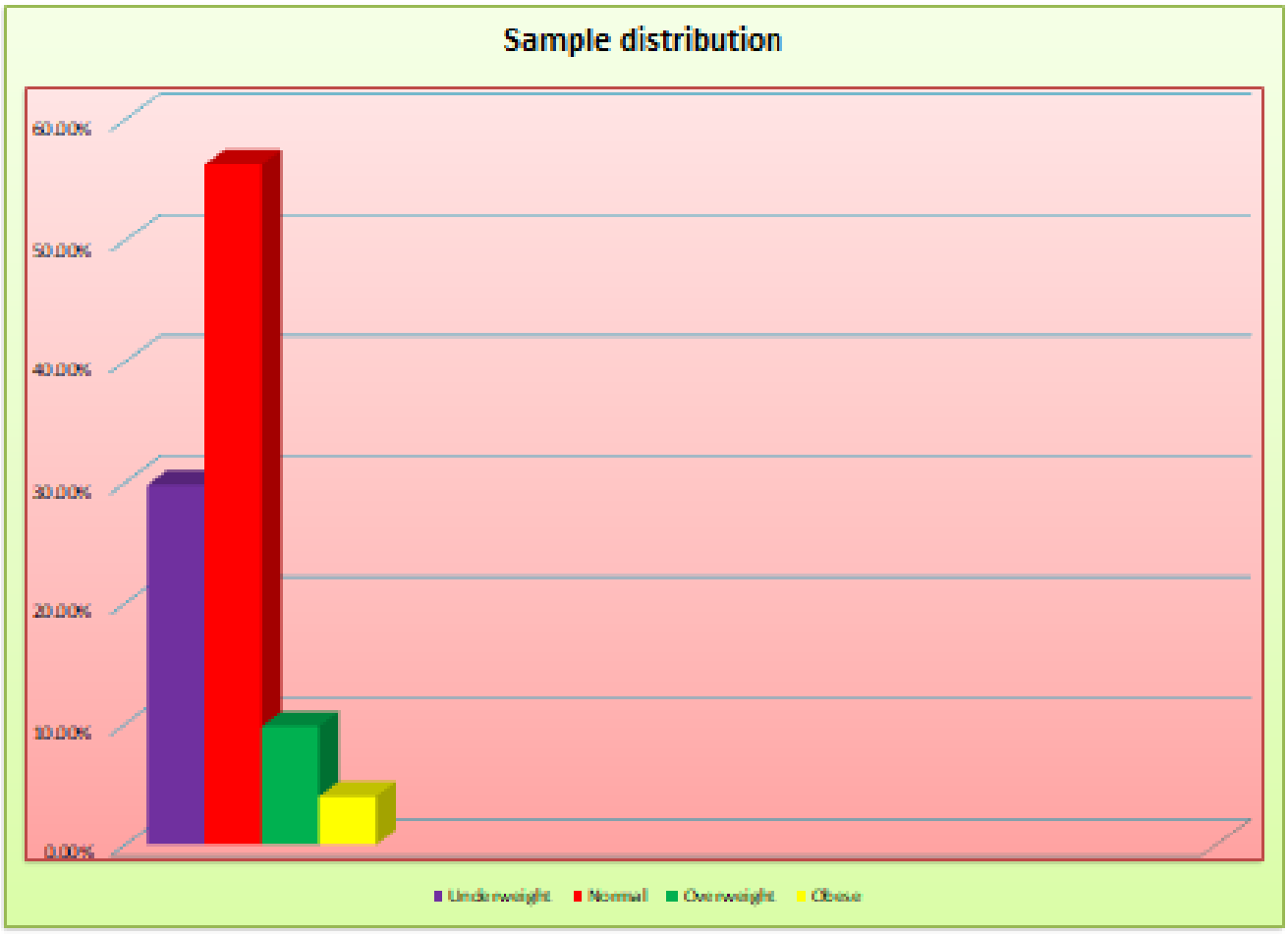

Figure 1.

In this study, the mean values of body fat percentage and total body fat for the studied subjects were 17.12 and 8.9, respectively. Body fat percentage and total body fat were significantly correlated with the selected body parameters (Table 2). The highest significant correlation of body fat percentage and total body weight were observed with body weight (r=0.924 & r=0.912), and with BMI (r=0.998 & r=0.954). In the assessment of blood pressure, it was observed that 190 participants (27.1%) suffered from hypotension, 388 participants (55.3%) were normal, 92 participants (13.1%) were classified as pre-hypertensive and 31 participants (4.4%) had hypertension (Table 3 – Table 5) and Figure 2.

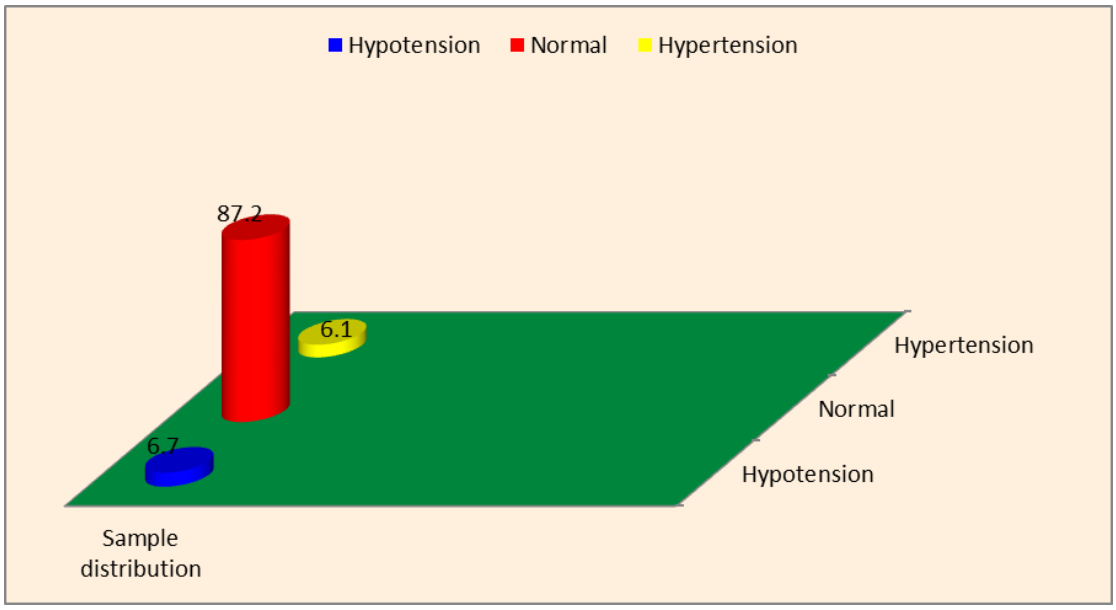

Figure 2.

4. Discussion

The present study provides data on anthropometric measurements and nutritional status of evaluation of a large sample of preparatory school students in Taif city, Saudi Arabia (Table 1 - Table 2).

Our data findings (Table 1 - Table 5) are in agreement with previous literature studies that confirmed that nutritional status is a vital factor in deciding the human health conditions [26]. Nutritional status is also an indicator of health status and well-being in any geographical region [27]. In this regard, the importance of the nutritional status of children in developing countries should be emphasized, not only for the improvement of children health in the coming generations, but also for the overall development of the concerned region in the near future [28]. Using BMI as an indicator, we found that 29, 8% of students were underweight, 9.8% were overweight, and 4% were obese (Table 3 - Table 4). In line with our results, it has been report that obesity among children and adolescent represents a new challenge for the coming generations [29-35]. In addition, table Table 5 compared the results of the nutritional status of the children in the present study with the results of other similar studies conducted in Saudi Arabia at different regions as well as in other countries. In this report, we supposed that overweight and obesity observed in preparatory school students may be attributed to changes of dietary habits and physical activity patterns. In addition, transport facilities and untargeted consumption of energy-dense foods (e.g. fats and sugar) could be reasons for increasing overweight and obesity among school children in Saudi Arabia. A significant correlation was found between BMI and body fat; BMI and waist; BMI and hip measurements where these findings are in agreement with other previous reports [36].

Interestingly, we found that BMI significantly correlated with increased systolic and diastolic blood pressure (Table 3 - Table 4). In this regard, it has been reported that obesity strongly correlated with increased blood pressure in children irrespective of ethnicity [37,38] suggesting the use of BMI as a predictor of blood pressure changes in children and adolescent.

We also found a statistically significant positive correlation between all the selected anthropometric measures and the blood pressure parameters (SBP and DBP). Previous studies showed a strong relationship between different anthropometric indicators and blood pressure levels [37]. Body composition variables such as weight, skin-fold thicknesses…etc had been shown to be significantly correlated with blood pressure readings. Although many studies have been conducted to delineate the best anthropometric predictor of high blood pressure in childhood and adolescent phase, the wide variety of results was considered as an obstacle to decide this issue. On the other hand, examining the relationships between BMI changes (Obesity indicators) and blood pressure levels would be of utmost important to set an early detection and prevention strategy of high blood pressure in children and adolescents. We found a positive correlation between BMI and fat percentage with systolic and diastolic levels (Pearson's correlation coefficient values). These results are consistent with other studies [38,39] that demonstrate a strong relationship between BMI and blood pressure levels across developed and developing countries [37,38]. The results of our study provide a lot of information that potentially support the use of BMI as an indicator to identify the health risks for developing future hypertension in male adolescents.

We found the estimated point prevalence of hypertension among adolescents (12-15 years in Taif City) to be 6.7%. This appears to be lower than that reported in Jeddah (17.2%) [40] and that reported in south-western region of Saudi Arabia (39%) [41]. In USA, it was reported that hypertension was found in 3.6% of children aged 3-18 years [42). The divergent results of studies concentrate on determination of hypertension prevalence in children and adolescents. That may be attributed to the criteria used to identify hypertension and pre-hypertension as well as population differences [43]. This may be secondary to changes in socioeconomic circumstances of the human communities and life styles [44].

5. Conclusions

Saudi Anthropometric measurements are comparable to international standards. The future life style changes (sedentary life, food type and exercise) impact development of diabetes melliyus and metabolic syndrome in the Saudi society.

BMI and percentage of body fat are important predictors of hypertension and blood pressure levels in adolescents. Thus, measurement of BMI and determination of body fat percentage have been suggested as screening tools for high blood pressure should become a routine approach in assessment of school students and could be simple clinical alternative of measuring blood pressure as there's no need for specialized health professional or technical apparatus**.** Weight management as well as life style modification programs are important for Saudi school students.

Statement of Competing Interests

No conflicts of interest to be declared.

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