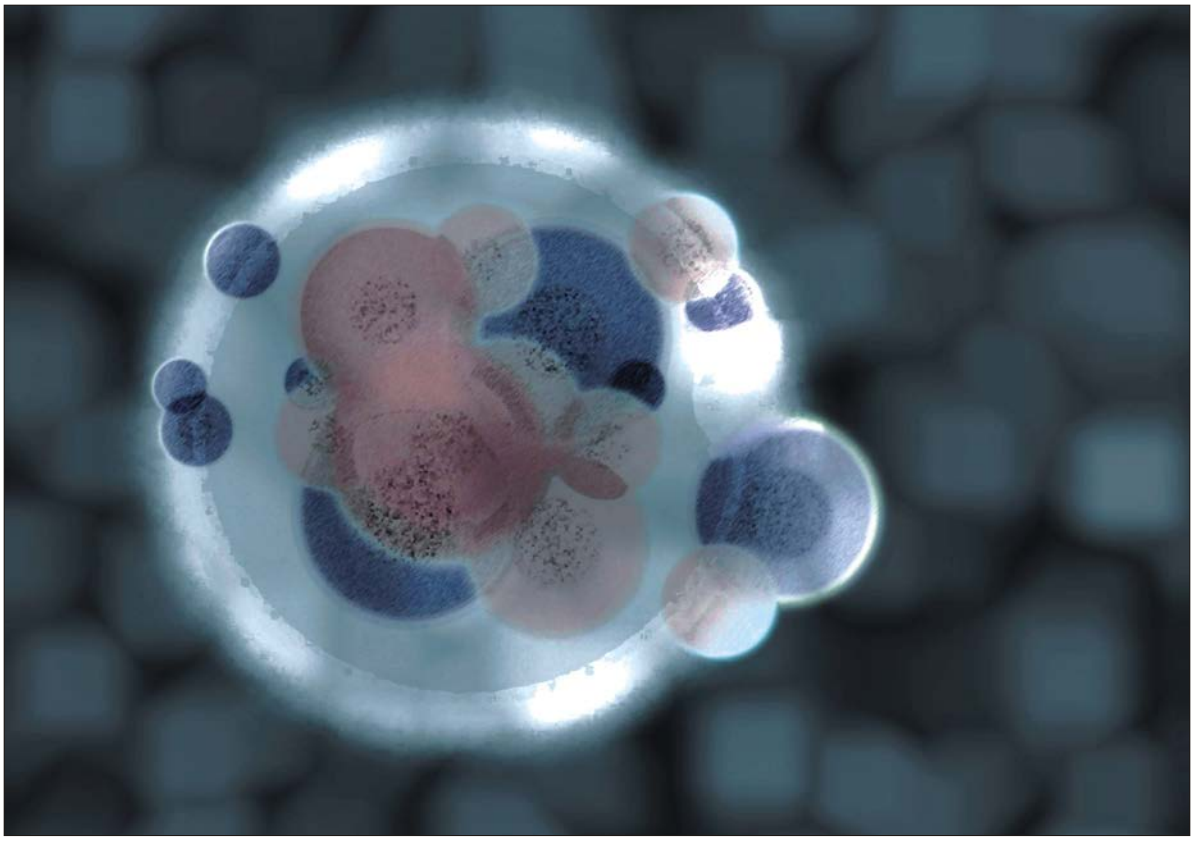

Journal of Biological Sciences

ISSN 1727-3048

science alert

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Journal of Biological Sciences 13 (3): 139-145, 2013
ISSN 1727-3048 / DOI: 10.3923/jbs.2013.139.145

Better Anthropometric Indicators to Predict Elevated Blood Pressure in North Indian Punjabi Adolescents

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Abstract: Punjabi population as an ethnic group is at high risk for obesity and hypertension. It is believed that these disorders begin in childhood especially in adolescent period. However, no such comprehensive study is available regarding the reference cut-off point for the different anthropometric indicators. Hence, the aim of the present study was to determine the better anthropometric predictor for detecting hypertension in North Indian Punjabi Adolescents. A cross-sectional study with a sample of 1225 (634 boys and 591 girls) adolescents aged 10 to 18 years was carried out. The study considered three anthropometric indicators such as Body Mass Index (BMI), waist circumference and waist to height ratio (WHtR). Sensitivity, specificity, likelihood ratio and odds ratios analysis were used to identify better predictor for detecting hypertension. The sensitivities with confidence interval were in boys BMI: 0.754 (0.633-0.846); waist circumference: 0.766 (0.616-0.872); WHtR: 0.640 (0.520-0.745) and for girls BMI: 0.581 (0.422-0.726); waist circumference: 0.656 (0.468-0.808); WHtR: 0.621 (0.424-0.787). The odds ratios were in boys BMI: 4.26 (2.40-7.55); waist circumference: 4.35 (2.17-8.71); WHtR: 2.36 (1.43-3.89) and for girls BMI: 2.17 (1.15-4.06); waist circumference: 2.98 (1.41-6.32); WHtR: 2.52 (1.17-5.44). The study suggests waist circumference is the better predictor to predict cardiovascular risk factors in adolescent boys as compared to girls and provide a baseline for further study.

Key words: Obesity, hypertension, adolescents, sensitivity and specificity

INTRODUCTION

Obesity and elevated blood pressure are the potential cardiovascular risk factor in every age group especially in adolescents. There is an abundant epidemiological evidence that anthropometric characteristics are significantly associated with cardiovascular mortality and morbidity (Yalcin *et al*., 2005; Latiffah and Hanachi, 2008; Latiffah *et al*., 2008; Owiredu *et al*., 2008; Bishnoi, 2010; Badaruddoza *et al*., 2010, 2011a, b; Gupta and Kapoor, 2012). The different cutoffs of different anthropometric indicators for detecting cardiovascular disease and obesity risk factors for adolescents have been used by various investigators (Cole *et al*., 2000; Yalcin *et al*., 2005; Krishna *et al*., 2006; Kuriyan *et al*., 2011; Virani, 2011). However, Body Mass Index (BMI) and waist to height ratio (WHtR) are widely used for detecting cardiovascular risk. The biological mechanism for the development of elevated blood pressure in adolescent is not better understood and is assumed to be associated with multiple reasons. However, genetic factors influence the susceptibility to a child of adolescent age to develop cardiovascular disease. Furthermore, environment factors, lifestyle and cultural environment have also played a major role to raise the prevalence of cardiovascular disease in adolescents. In India, many studies have confirmed that there are considerable increase in hypertension and obesity in adolescent age group (Mohan *et al*., 2004; Singh *et al*., 2006; Gupta *et al*., 2007; Virani, 2011). However, the relation between BMI, WHtR and Waist Circumference (WC) with elevated blood pressure in adolescents has not been well studied, particularly in Punjabi adolescent population. Therefore, early detection of hypertension and risk factors of blood pressure among adolescents would be important preventive measure in the population. It is also important to note that the risk factors related to elevated blood pressure such as BMI, WC and WHtR tend to cluster in adolescents. The present study examines the relative importance of different anthropometric indicators to predict hypertension in North Indian Punjabi adolescent population.

MATERIALS AND METHODS

For data collection, independent random samples had been drawn from urban localities of the Punjab among adolescents aged from 10-18 years. Subjects were selected

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from government and private schools, in order to recruit them from different socioeconomic strata. A total of 1225 adolescents aged 10-18 years consisted 634 boys and 591 girls were enrolled from 10 schools of urban areas of Punjab, to identify accurate and significant anthropometric predictors for cardiovascular diseases. Data were collected from eight districts (Amritsar, Faridkot, Moga, Muktsar, Gurdaspur, Fatehgarh Sahib, Bathinda and Ferozpur) in the state of Punjab. Written informed consent was obtained from all the parents of subjects prior to their participation. Study was carried out through subsequent visit in the school of randomly selected subjects. The study was approved by Guru Nanak Dev University appropriate research ethics committee in the year 2010. The recruitment of subjects was done on school to school basis. Data collection and personal interviews were also done with each subject. General information about name, sex, date of birth, religion, caste, address and information related to life style habits like smoking, alcohol intake and food habits were recorded on the pre-designed Performa. All measurement and interviews have been taken by single investigator with same instrument, therefore, intra and inter observer variability for taking measurements were very negligible.

Anthropometric measurement: The anthropometric measurements like height (cm), weight (kg), waist circumference (cm) and hip circumference (cm) were taken on each individual using standard anthropometric techniques (Singh and Bhasin, 1968; Weiner and Lourie, 1981). The age of the adolescents was determined directly from their reported date of birth in the school records. The height was measured using anthropometric rod with the standing erect position with the head in ear-eye plane. The reading was then, recorded to the nearest 0.1 cm. The weight of the subject was measured in kilograms by making them stand on a weighing machine with minimal clothing. Weight was recorded with an allowance deducted for clothing to the nearest 0.5 kg. Waist circumference was measured using a steel tape. The measurement was taken mid-way between the inferior margin of the last rib and crest of the ilium in a horizontal plane with relaxed abdomen. The tape was fitted snuggly without compressing the soft tissue. Hip circumference of the subject was taken with steel tape fitted around the pelvis at the point of maximal protrusion of buttocks while the subject was standing with his/her feet close to each other. The readings were recorded for waist and hip circumferences to the nearest 0.1 cm. The values for BMI expressed as the ratio of body weight divided by body height squared (kg m^{-2}), Waist to Hip Ratio (WHR) defined as waist circumference (cm) divided by hip circumference (cm), similarly waist to height ratio (WHtR) defined as waist circumference (cm) divided by height (cm) and the conicity index (C index) was determined by measuring weight, height and waist circumference using the following mathematical equation:

$$\text{C index} = \frac{\text{Waist circumference (m)}}{0.109\sqrt{\text{Body weight (kg)/Height (m)}}}$$

Physiometric measurement: The blood pressure was measured with standardized mercury sphygmomanometer and a stethoscope by following the recommendations of American Heart Association (Kumar *et al*., 2011). Blood pressure was measured in sitting posture with the hands resting on examining table with the cubital fossa supported at the level of the heart. The stethoscope was placed over the brachial artery pulse, proximal and medial to the cubital fossa and below the bottom edge of the cuff (i.e., about 2 cm above the cubital fossa). On the basis of circumference of the participant's arm, a regular adult or small or medium cuff was chosen. The systolic blood pressure is defined as the appearance of the first sound (Korotkoff phase 1) and diastolic blood pressure is defined as the disappearance of sound (Korotkoff phase 5). The average of the two blood pressure measurements was used as the estimate of Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP) in the present analysis. However, the variation of two readings was negligible. Mean arterial blood pressure (MBP) was simply estimated as DBP+(SBP-DBP)/3. To calculate the pulse rate, the radial artery at the wrist was used to feel the pulse. It was count over one minute.

Statistical analysis: Data were analyzed using SPSS software 17.0 version. Base line characteristics were summarized with mean and standard deviations. The comparisons of baseline characteristics were compared with t-statistics. The sensitivity, specificity, likelihood ratio and odds ratio were calculated for every anthropometric indicator. Likelihood ratio is defined as sensitivity/(1-specificity). The Confidence Intervals (CI) were also calculated to determine the lower and upper limit of predictive ability of these anthropometric indicators. The $p<0.05$ level was selected as the criterion of statistical significance.

RESULTS

Of the total 1225 adolescents aged 10-18 years investigated, 51.76% were boys (634) and 48.24% were girls (591). The descriptive data of both boys and girls are shown in Table 1. The mean age of boys and girls are

Table 1: Baseline characteristics of the Punjabi adolescent aged 10-18 years

	Boys (n = 634)		Girls (n = 591)		
Characteristics	Mean	SD	Mean	SD	p-value
Age (years)	13.59	2.34	13.90	2.45	<0.024
Height (cm)	154.64	15.41	152.54	10.02	<0.005
Weight (kg)	42.88	13.69	41.12	10.02	<0.011
Body mass index (kg m^{-2})	17.50	3.19	17.47	2.98	0.865
Waist circumference (cm)	63.57	9.16	61.88	7.39	<0.001
Hip circumference (cm)	76.88	10.38	78.82	9.81	<0.001
Waist to hip ratio	0.83	0.07	0.79	0.07	0.348
Systolic blood pressure (mmHg)	122.03	13.70	121.63	14.24	0.616
Diastolic blood pressure (mmHg)	82.73	12.08	82.57	11.77	0.815
Mean arterial blood pressure (mmHg)	95.84	12.01	95.54	11.84	0.660
Pulse rate (count min^{-1})	76.94	6.71	76.62	7.16	0.420
Waist to height ratio	0.41	0.05	0.41	0.04	1.000
Conicity index	1.12	0.07	1.10	0.07	<0.001

Table 2: Prevalence of hypertension by sex in Punjabi adolescents aged 10-18 years through obesity parameters

	Boys		Girls		Total	
Obesity parameter	Normo-tensive	Hyper-tensive	Normo-tensive	Hyper-tensive	Normo-tensive	Hyper-tensive
Body mass index (BMI)						
Normal	329 (51.89)	236 (37.23)	334 (56.51)	214(36.21)	663 (54.12)	450 (36.73)
Overweight	8 (1.26)	26 (4.10)	10 (1.69)	15 (2.55)	18 (1.47)	41 (3.35)
Obese	9 (1.42)	26 (4.10)	8 (1.35)	10 (1.69)	17 (1.39)	36 (2.94)
Waist circumferences (WC)						
Normal	335 (52.84)	252 (39.75)	341 (57.70)	218 (36.89)	676 (55.18)	470 (38.37)
Overweight	7 (1.10)	12 (1.89)	8 (1.35)	13 (2.20)	15 (1.22)	25 (2.05)
Obese	4 (0.63)	24 (3.79)	3 (0.51)	8 (1.35)	7 (0.57)	32 (2.61)
Waist to height ratio						
Normal	319 (50.32)	240 (37.85)	341 (57.70)	221 (37.39)	660 (53.88)	461 (37.63)
Overweight	19 (3.00)	21 (3.31)	8 (1.35)	13 (2.20)	27 (2.20)	34 (2.78)
Obese	8 (1.26)	27 (4.26)	3 (0.51)	5 (0.85)	11 (0.90)	32 (2.61)

Values in parenthesis indicate percentage

13.59±2.34 and 13.90±2.45 years, respectively. The mean values of height, weight, waist circumference and conicity index are significantly ($p<0.001$) higher in boys as compared to girls. However, only hip circumference was significantly ($p<0.001$) higher in girls. The mean values of other variables such as BMI, WHR, SBP, DBP and pulse rate are consistently higher in boys as compared to girls but the differences are not statistically significant.

The mean prevalence of arterial hypertension for total subjects with normal BMI, waist circumference and WHtR were 36.73% (37.23% in boys and 36.21% in girls), 38.37% (39.75% in boys and 36.89% in girls) and 37.63% (37.85% in boys and 37.39% in girls), respectively. Similarly, the mean prevalence of arterial hypertension for total overweight subjects in both sexes with respect to BMI, waist circumference and WHtR were 3.35% (4.10% in boys and 2.55% in girls), 2.05% (1.89% in boys and 2.20% in girls) and 2.78% (3.31% in boys and 2.20% in girls), respectively. The mean prevalence of arterial blood pressure for total obese subjects with respect to BMI, waist circumference and WHtR were 2.94% (4.10% in boys and 1.69% in girls), 2.61% (3.79% in boys and 1.35% in girls) and 2.61% (4.26% in boys and 0.85% in girls), respectively (Table 2).

Comparisons were made between normotensive and hypertensive with respect to anthropometric and physiometric characteristics (Table 3). The mean differences of BMI, waist circumference, SBP, DBP, MBP and WHtR were statistically significant between normotensive and hypertensive boys, girls and total subjects. However, the differences of means of other variables such as age and height in boys; weight, hip circumference and pulse rate in girls and total subjects have found significant ($p<0.001$) between normotensive and hypertensive. The mean values of hypertension related risk factors such as BMI (18.16 vs. 16.95 for boys and 18.28 vs. 16.92 for girls), WC (64.46 vs. 62.83 for boys and 63.77 vs. 60.59 for girls), pulse rate (77.45 vs. 76.51 for boys and 77.74 vs. 75.85 for girls), WHtR (0.42 vs. 0.40 for both boys and girls) among hypertensive groups observed significantly ($p<0.001$) higher as compared to normotensive groups.

The prevalence of obesity with respect to the anthropometric indicators such as BMI, waist circumference and waist/height ratio for boys and girls are given in Table 4. The percentage prevalence of overweight has been observed in boys 5.36, 3.00, 6.31 and in girls 4.23, 3.55, 3.55 using BMI, waist circumference and

Table 3: Comparison of baseline characteristics of hypertensive and normotensive punjabi adolescent aged 10-18 years

	Boys			Girls			Total		
Characteristics	Normotensive (n=346)	Hypertensive (n = 288)	p-value	Normotensive (n = 352)	Hypertensive (n = 239)	p-value	Normotensive (n = 698)	Hypertensive (n = 527)	p-value
Age (years)	13.95±2.200	13.17±2.430	<0.001	13.75±2.270	14.11±2.680	0.079	13.85±2.240	13.97±2.720	0.398
Height (cm)	156.12±14.11	152.87±16.69	<0.008	152.27±10.03	152.93±10.01	0.432	154.18±12.36	152.90±14.05	0.091
Weight (kg)	41.96±10.76	44.00±16.48	0.062	39.67±8.850	43.25±11.22	<0.001	40.80±9.900	43.66±14.33	<0.001
BMI (kg m^{-2})	16.95±2.390	18.16±3.840	<0.001	16.92±2.450	18.28±3.470	<0.001	16.93±2.420	18.22±3.680	<0.001
Waist circum (cm)	62.83±6.890	64.46±11.26	<0.026	60.59±6.030	63.77±8.700	<0.001	61.70±6.560	64.15±10.18	<0.001
Hip circum (cm)	76.80±8.240	76.97±12.49	0.838	77.56±8.780	80.68±10.91	<0.001	77.19±8.520	78.65±11.94	<0.013
WHR	0.82±0.060	0.84±0.060	<0.001	0.79±0.070	0.79±0.060	1.000	0.80±0.070	0.82±0.070	<0.001
SBP (mmHg)	113.68±9.850	132.07±10.57	<0.001	112.60±8.650	134.94±9.710	<0.001	113.14±9.270	133.37±10.28	<0.001
DBP (mmHg)	76.72±10.01	89.95±10.28	<0.001	76.68±8.640	91.26±10.30	<0.001	76.70±9.330	90.54±10.30	<0.001
MBP (mmHg)	89.06±9.330	104.00±9.560	<0.001	88.70±7.900	105.63±9.150	<0.001	88.88±8.640	1.05±9.400	<0.001
Pulse rate	76.51±6.760	77.45±6.610	0.079	75.85±6.890	77.74±7.410	<0.002	76.18±6.830	77.58±6.980	<0.001
WHtR	0.40±0.040	0.42±0.050	<0.001	0.40±0.040	0.42±0.050	<0.001	0.40±0.040	0.42±0.050	<0.001
Conicity index	1.12±0.070	1.12±0.080	1.000	1.10±0.070	1.11±0.080	0.108	1.11±0.070	1.12±0.080	<0.020

BMI: Body mass index, Waist circum.: Waist circumference, Hip circum.: Hip circumference, WHR: Waist hip ratio, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MBP: Mean arterial blood pressure and WHtR: Waist to height ratio

Table 4: Prevalence of Obesity by sex in Punjabi adolescents aged 10-18 years through obesity parameters

Obesity parameter	Boys (n = 634)	Girls (n = 591)	Total (n = 1225)
Body mass index			
Normal	565 (89.12)	548 (92.72)	1113 (90.86)
Overweight	34 (5.36)	25 (4.23)	59 (4.81)
Obese	35 (5.51)	18 (2.28)	53 (4.33)
Waist circumference			
Normal	587 (92.59)	559 (94.59)	1146 (93.55)
Overweight	19 (3.00)	21 (3.55)	40 (3.27)
Obese	28 (4.42)	11 (1.86)	39 (3.18)
Waist to height ratio			
Normal	559 (88.17)	562 (95.09)	1121 (91.51)
Overweight	40 (6.31)	21 (3.55)	61 (4.98)
Obese	35 (5.52)	8 (1.35)	43 (3.51)

Values in parenthesis indicate percentage

Table 5: Sensitivity, specificity and likelihood ratio with confidence interval of anthropometric indicators associated with hypertension

Anthropometric Indicators	Sensitivity (95% confidence interval)	Specificity (95% confidence interval)	Likelihood ratio (95% confidence interval)
Boys			
Body mass index (BMI)	0.754 (0.633-0.846)	0.582 (0.540-0.623)	1.804 (1.528-2.131)
Waist circumference (WC)	0.766 (0.616-0.872)	0.571(0.529-0.611)	1.784 (1.485-2.144)
Waist to height ratio (WHtR)	0.640 (0.520-0.745)	0.571 (0.528-0.612)	1.491 (1.227-1.811)
Girls			
Body mass index (BMI)	0.581 (0.422-0.726)	0.609 (0.567-0.650)	1.489 (1.132-1.959)
Waist circumference (WC)	0.656 (0.468-0.808)	0.610 (0.568-0.650)	1.683 (1.283-2.207)
Waist to height ratio (WHtR)	0.621 (0.424-0.787)	0.607 (0.565-0.647)	1.578 (1.166-2.136)
Total			
Body mass index (BMI)	0.688 (0.592-0.770)	0.596 (0.566-0.625)	1.700 (1.473-1.963)
Waist circumference (WC)	0.722 (0.608-0.814)	0.590 (0.561-0.618)	1.759 (1.509-2.051)
Waist to height ratio (WHtR)	0.635 (0.534-0.725)	0.589 (0.559-0.618)	1.543 (1.313-1.814)

BMI: Body mass index, WC: Waist circumference, WHtR: Waist to height ratio

waist/height ratio as the indicators, respectively. Whereas, the percentage prevalence of obese has been identified as in boys 5.51, 4.42, 5.52 and in girls 2.28, 1.86, 1.35 using BMI, waist circumference and waist/height ratio as the indicators, respectively. However, as a whole the highest percentage of overweight (4.98%) and obese (4.33%) have been observed using waist/height ratio and BMI as the indicators, respectively.

Sensitivity and specificity for predicting hypertension by different anthropometric indicators are summarized in Table 5. Sensitivity for predicting hypertension by different anthropometric indicators such as BMI, waist circumference and WHtR cutoff points varied in total subjects 63.5-72.2%; in boys 64.0-76.6%; in girls 58.1-65.6% and specificity varied in total subjects 58.9-59.6%; in boys 57.1-58.2%; in girls 60.7-61.0%. The positive likelihood ratio varied in total subjects 1.54-1.759; in boys 1.49-1.80; in girls 1.48-1.68. The values of specificities are almost equal for all anthropometric indicators. However, sensitivity is higher for waist

Table 6: Odds ratio of hypertension in obese punjabi adolescents aged 10-18 years determined by the appropriable cutoff points of anthropometric indicators

Anthropometric indicators	Odds ratio	95% confidence interval	p-value
Boys			
Body mass index (BMI)	4.26	2.40-7.55	<0.0001
Waist circumference (WC)	4.35	2.17-8.71	<0.0001
Waist to height ratio (WHtR)	2.36	1.43-3.89	<0.0005
Girls			
Body mass index (BMI)	2.17	1.15-4.06	<0.014
Waist circumference (WC)	2.98	1.41-6.32	<0.003
Waist to height ratio (WHtR)	2.52	1.17-5.44	<0.015
Total			
Body mass index (BMI)	3.07	2.04-4.62	<0.0001
Waist circumference (WC)	3.73	2.25-6.18	<0.0001
Waist to height ratio (WHtR)	2.49	1.64-3.77	<0.0001

circumference (72.2%) for total subjects, in boys (76.6%) and in girls (65.6%). The likelihood ratio has also maximum for waist circumference in total subjects (1.759) and in girls (1.683). Therefore, waist circumference would be considered better predictor of hypertension in adolescents.

Logistic regression was performed to see the different anthropometric indicators such as BMI, waist circumference and WHtR independently increased the risk of having hypertension among boys, girls and total subjects (Table 6). The odds ratios for BMI, waist circumference and WHtR were significant ($p<0.001$) in boys, girls and total subjects. The odds ratios of waist circumference in boys (4.35), girls (2.98) and total subjects (3.73) were higher as compared to BMI and WHtR. Therefore, prevalence of hypertension was significantly higher in those adolescents who had higher waist circumference.

DISCUSSION

Hypertension, overweight and obesity are the major health problems among present day Punjabi adolescents population. The major objective of present study is to compare three anthropometric indicators such as BMI, waist circumference and WHtR and to identify which anthropometric indicator is better discriminator for obesity and cardiovascular risk among adolescents. However, BMI was traditionally been used to measure obesity and hypertension in different epidemiological studies, whereas, other indicators such as waist circumference and waist to height ratio have also been popularly used by different investigators (Afridi *et al*., 2003; Sidhu *et al*., 2004; Ashwell and Hsieh, 2005; Bigaard *et al*., 2005; Feldstein *et al*., 2005; Welborn and Dhaliwal, 2007; Alhamdan, 2008; Sung *et al*., 2008; Badaruddoza and Kumar, 2009; Beck *et al*., 2011). According to BMI cut-off points, 37.23% boys and 36.21% girls and 36.73% of total subjects with normal BMI have been identified with hypertension, respectively. Also according to waist circumference cut-off points, 39.75, 36.89 and 38.37% of boys, girls and total subjects with normal waist circumference have been identified with hypertension. The similar results according to waist to height ratio cut-off points, 37.85, 37.39 and 37.63% of boys, girls and total subjects have been identified with hypertension with normal WHtR. Therefore, waist circumference was more important to identify high risk cardiovascular disease among adolescent subjects. Similar to present results many investigators used waist circumference as the important criteria to identify the high risk subjects for obesity and hypertension (Yalcin *et al*., 2005; Badaruddoza and Sawhney, 2009; Badaruddoza and Kaur, 2012; Huxley *et al*., 2010). Furthermore, genetic, environments and dietary intake have also contributed a significant proportion of anthropometric and physiometric variation (Tassaduqe *et al*., 2004; Mahajan *et al*., 2009; Afoakwah and Owusu, 2011; Badaruddoza and Patharia, 2012). However, all these anthropometric indicators (BMI, waist circumference and WHtR) were good predictors but population and ethnic specific differences have also been found. Although, by comparing the sensitivity, specificity and likelihood ratios of these three indicators, not so much differences between BMI and waist circumference have been found in both sexes and combined subjects. Therefore, these two anthropometric indicators (BMI and waist circumference) can be used to predict the elevated blood pressure in adolescents. Many other studies in different population have also suggested that BMI and waist circumference would be good predictor for hypertension in adolescents (Katzmarzyk *et al*., 2004; Sung *et al*., 2006; Beck *et al*., 2011; Gupta and Kapoor, 2012). For an odds ratio analysis from the present study it has also been observed that all three anthropometric indicators (BMI, waist circumference and WHtR) have significant association with hypertensive obese Punjabi adolescents in both and combined sexes. However, increasing risk of hypertension in obese adolescents was found to be associated with increasing waist circumference in both and combined sexes, although, adolescent boys are more prone to develop hypertension with increasing waist circumference as compared to girls. The odds ratio of boys was much higher (4.35) as compared to girls (2.95).

CONCLUSION

In conclusion, waist circumference is more important and better anthropometric indicator for detecting cardiovascular risk factor among adolescent boys as compared to adolescent girls.

ACKNOWLEDGMENT

The financial assistance to SK Brar, Maulana Azad National Fellowship from UGC, New Delhi is gratefully acknowledged. Conflict of Interest: No conflict of interest was declared.

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