Original Article

Age-specific Differences and Interrelation between Anthropometric Variables in Pakistani Children aged 2 to 19 Years

Asif Muhammad, Aslam Muhammad, Sajid Mustafa, Saima Altaf

Department of Statistics, Govt. College, Qadirpur Raan, Multan, Sahiwal Medical College & DHQ Teaching Hospital, Sahiwal and Department of Pediatrics, Bahauddin Zakariya University, Multan, Pakistan

Objective: To determine the age-specific interrelation between body mass index (BMI) and other obesity related indicators and to determine age and gender-differences of anthropometric characteristics in the Pakistani children aged 2-19 years.

Methodology: Anthropometric measurements included height, weight and body circumferences and their derived indices BMI, waist-to-hip ratio (WHR), waist-to-height ratio (WHtR) were taken from a cross-sectional sample of 10782 Pakistani children, aged 2-19 years during March to June, 2016. The data were analyzed using descriptive statistics, independent t-test and the Pearson correlation co-efficient.

Results: BMI had a strongest positive and significant correlation with mid-upper arm circumference (MUAC) in all age-groups of boys and girls. BMI had weakest correlation with WHR in all age-groups for both genders. The mean comparisons between both genders showed that boys had a higher mean value in various age-groups than those of girls had with few exceptions.

Conclusion: There was considerable interrelationship among different anthropometric measures in boys and girls of aged 2 to 19 years. However, the MUAC had strong positive correlation with BMI in both genders and MUAC therefore, could be proposed as a simple and easy index to discriminate children and adolescent with elevated BMI. (Rawal Med J 201;43:164-169).

Key words: Body Mass Index, Mid-Upper-Arm Circumference, Head circumference, Waist-to-hip ratio.

INTRODUCTION

Evaluation of nutritional status is necessary for understanding the health of an individual or population. This becomes most crucial especially during childhood and the juvenile years, when the level of hydration and the adipose tissues experience significant changes.[1,2] According to WHO, anthropometry is the most extensive and internationally applicable method used for understanding the human biological variability over time.[3] It is mainly concerned with the measurement of physical sizes and shapes of human body.

Body composition changes are directly reflected in anthropometric measures and are different in both genders. Body mass index (BMI) has long been reputed criterion used for defining general obesity in both children and adults. Some other studies also have shown the value of waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) as a measure of central obesity.[4,5] In addition to these, mid-upper-arm circumference (MUAC), neck circumference (NC) and wrist circumference (WrC) have recently been proposed as some other reliable indicators of obesity children and adults.[6,7]

Few studies[8,9] about children have tried to see the interrelationship between anthropometric variables that have potential to predict obesity and cardiovascular risk. However, in Pakistan, no one has conducted such study in children to see how BMI and other anthropometric indicators of weight status are associated with gender during different ages. This negotiable gap led the present study. After studying the interrelation of BMI with the other anthropometric measures, it would be possible to seek anthropometric variable(s) that can easily be used as a proxy measure for large sample studies. Because in many studies with large sample but limited resources, measurement of height, weight and WC etc. may become too difficult task and respondents' clothing is one of the major disturbing factor. From this study results, we therefore, can hope to use a more convenient and the best proxy measure in place of BMI for determining the

overweight and obesity status of children and adolescents.

METHODOLOGY

This population based cross-sectional study sample of 10782 children aged 2-19 years was collected from Pakistan's most populated province viz. Punjab. Three major cities Multan, Lahore and Rawalpindi and the capital city, Islamabad were purposively selected. The data about children aged 4-19 years were collected from different public and private schools (primary, secondary and higher secondary), while the data for the rest of the age-groups were collected from different public places. All the healthy children aged 2-19 year old, who were not taking any medication and having not any physical disability were included in the study. All children who did not meet these criteria were excluded. Verbal consent was taken from each child's parents or guardians of under five years. While, written consent from each school's head was taken for school going children. The study was approved by the Departmental Ethics Committee of Bahauddin Zakariya University, Multan. Pakistan.

Data collection activity was completed during March to June, 2016 by three well-trained data collection teams. Each team consisted of three members, supervised by the principal investigator. The required information was taken through a self-administered questionnaire, comprising of demographic information section and measurement section. Demographic section contained the information like gender (boys/girls) and age (rounded to next year) of children etc. The measurement section contained the information about the anthropometric measurements. Height, weight, head circumference (HdC), neck circumference (NC), chest circumference (ChC), waist circumference (WC), hip circumference (HC), mid-upper-arm circumference (MUAC) and wrist circumference (WrC) of each subject were taken by trained personnel according to the WHO recommendations.[3,10]

Height (cm) without shoes was taken on a stadiometer, and weight (Kg) in light cloths was measured using weighing machine. All the body circumferences were measured in centimeters using a stretch-resistant measuring tape without squeezing the skin. The measurement of HdC was made by wrapping the tape on a line passing over the glabella to the area near the top of the occipital bone as to get maximum circumference. NC was measured at the level of the thyroid cartilage. WC was measured midway between the lowest rib and the high point of the iliac crest at the end of normal expiration. HC was measured at the level of maximal portion of buttocks. The MUAC was measured at the midway between the olecranon and acromion process on the upper left arm. WrC was measured on the left arm wrist at the bony prominences of the radial and ulnar styloid. The BMI on each individual was obtained by weight in kilogram divided to the square of his height in meters ($BMI=Kg/m^2$). While, waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) were obtained by dividing waist circumference to hip circumference and waist circumference divided to height, respectively.

Analysis of variance (ANOVA) technique was used to identify any mean difference between the age-groups in both boys and girls. Two-sample independent t-test was used check the mean difference between boys and girls according in different age-group. Pearson's correlation was used to investigate the correlation between anthropometric measures. SPSS version 21.0 was used for all the statistical analyses.

RESULTS

A total of 10782 (5593 boys and 5189 girls) children aged 2-19 years were included in the study. About half (49.6%) of the children belonged to the age-group of 6-12 years. The age-specific values of correlation co-efficient of BMI with other anthropometric characteristics are displayed in Table 1. In the parentheses of lower left triangle, the correlation between BMI and obesity related indicators for girls were shown. On the other hand, for boys, the correlation between BMI and other obesity related indicators were shown in the upper right triangle of the table. For instance, the correlation coefficient between BMI and HdC was 0.25 for girls of age-group 2-5 years and the figure for similar age group of boys was 0.27. We found

that BMI had a strongest positive and significant correlation with MUAC in all age-groups of both sexes. Among boys, the said correlation coefficients were 0.48, 0.63 and 0.70 for the age groups of 2-5, 6-12 and 13-19 years, respectively. On the other side, for girls of the same age groups, the respective coefficients were 0.46, 0.68 and 0.53. However, BMI marginally correlates with WHR in all age-groups for both boys and girls.

Table 1. Correlation between anthropometric indices of studied subjects by age-groups and gender.

Variables	Age-groups	BMI	HdC	NC	ChC	WC	HC	WHR	WHtR	MUAC	WrC
BMI	02-05	1	0.27[a]	0.40[a]	0.46[a]	0.37[a]	0.44[a]	0.00[a]	0.34[a]	0.48[a]	0.38[a]
	06-12	1	0.32[a]	0.52[a]	0.55[a]	0.54[a]	0.56[a]	0.07[a]	0.44[a]	0.63[a]	0.48[a]
	13-19	1	0.41[a]	0.64[a]	0.62[a]	0.52[a]	0.68[a]	-0.06[a]	0.44[a]	0.70[a]	0.51[a]
HdC	02-05	(0.25)[a]	1	0.39[a]	0.56[a]	0.43[a]	0.48[a]	0.04[a]	0.11[a]	0.46[a]	0.39[a]
	06-12	(0.48)[a]	1	0.52[a]	0.43[a]	0.38[a]	0.45[a]	-0.01[C]	0.11[a]	0.48[a]	0.44[a]
	13-19	(0.43)[a]	1	0.58[a]	0.45[a]	0.38[a]	0.49[a]	-0.02[C]	0.15[a]	0.50[a]	0.42[a]
NC	02-05	(0.31)[a]	(0.35)[a]	1	0.49[a]	0.39[a]	0.42[a]	0.05[C]	0.21[a]	0.48[a]	0.39[a]
	06-12	(0.60)[a]	(0.60)[a]	1	0.61[a]	0.58[a]	0.64[a]	0.02[C]	0.27[a]	0.65[a]	0.57[a]
	13-19	(0.49)[a]	(0.51)[a]	1	0.73[a]	0.58[a]	0.74[a]	-0.03[C]	0.25[a]	0.75[a]	0.63[a]
ChC	02-05	(0.38)[a]	(0.38)[a]	(0.56)[a]	1	0.68[a]	0.73[a]	0.08[C]	0.22[a]	0.64[a]	0.55[a]
	06-12	(0.65)[a]	(0.52)[a]	(0.68)[a]	1	0.72[a]	0.77[a]	0.06[a]	0.36[a]	0.66[a]	0.57[a]
	13-19	(0.44)[a]	(0.28)[a]	(0.37)[a]	1	0.59[a]	0.73[a]	0.00[C]	0.30[a]	0.68[a]	0.54[a]
WC	02-05	(0.40)[a]	(0.31)[a]	(0.46)[a]	(0.69)[a]	1	0.49[a]	0.63[a]	0.71[a]	0.57[a]	0.55[a]
	06-12	(0.59)[a]	(0.47)[a]	(0.66)[a]	(0.73)[a]	1	0.69[a]	0.52[a]	0.78[a]	0.64[a]	0.56[a]
	13-19	(0.44)[a]	(0.28)[a]	(0.37)[a]	(0.56)[a]	1	0.61[a]	0.60[a]	0.83[a]	0.56[a]	0.45[a]
HC	02-05	(0.38)[a]	(0.32)[a]	(0.47)[a]	(0.67)[a]	(0.55)[a]	1	-0.36[a]	0.01[C]	0.60[a]	0.51[a]
	06-12	(0.63)[a]	(0.50)[a]	(0.68)[a]	(0.79)[a]	(0.73)[a]	1	-0.25[a]	0.28[a]	0.70[a]	0.60[a]
	13-19	(0.46)[a]	(0.35)[a]	(0.45)[a]	(0.67)[a]	(0.60)[a]	1	-0.26[a]	0.28[a]	0.72[a]	0.56[a]
WHR	02-05	(0.12)[a]	(0.07)[b]	(0.11)[a]	(0.20)[a]	(0.67)[a]	(-0.29)[a]	1	0.74[a]	0.08[b]	0.13[a]
	06-12	(0.06)[a]	(0.05)[a]	(0.10)[a]	(0.07)[a]	(0.52)[a]	(0.19)[a]	1	0.71[a]	0.03[C]	0.04[b]
	13-19	(0.02)[c]	(-0.05)[C]	(-0.05)[b]	(-0.07)[a]	(0.49)[a]	(0.39)[a]	1	0.72[a]	-0.04[C]	0.00[C]
WHtR	02-05	(0.42)[a]	(0.08)[a]	(0.26)[a]	(0.39)[a]	(0.79)[a]	(0.22)[a]	(0.70)[a]	1	0.26[a]	0.27[a]
	06-12	(0.47)[a]	(0.19)[a]	(0.32)[a]	(0.38)[a]	(0.78)[a]	(0.34)[a]	(0.68)[a]	1	0.34[a]	0.26[a]
	13-19	(0.40)[a]	(0.11)[a]	(0.16)[a]	(0.38)[a]	(0.87)[a]	(0.38)[a]	(0.58)[a]	1	0.30[a]	0.23[a]
MUAC	02-05	(0.46)[a]	(0.32)[a]	(0.48)[a]	(0.60)[a]	(0.55)[a]	(0.56)[a]	(0.14)[a]	(0.28)[a]	1	0.62[a]
	06-12	(0.68)[a]	(0.51)[a]	(0.70)[a]	(0.73)[a]	(0.70)[a]	(0.74)[a]	(0.08)[a]	(0.40)[a]	1	0.67[a]
	13-19	(0.53)[a]	(0.37)[a]	(0.47)[a]	(0.55)[a]	(0.53)[a]	(0.65)[a]	(-0.07)[a]	(0.33)[a]	1	0.68[a]
WrC	02-05	(0.30)[a]	(0.32)[a]	(0.37)[a]	(0.44)[a]	(0.41)[a]	(0.40)[a]	(0.13)[a]	(0.16)[a]	(0.54)[a]	1
	06-12	(0.54)[a]	(0.47)[a]	(0.62)[a]	(0.66)[a]	(0.65)[a]	(0.67)[a]	(0.10)[a]	(0.36)[a]	(0.71)[a]	1
	13-19	(0.38)[a]	(0.29)[a]	(0.36)[a]	(0.45)[a]	(0.38)[a]	(0.45)[a]	(-0.03)[C]	(0.18)[a]	(0.68)[a]	1

Pearson correlation co-efficient for boys in upper right corner; for girls in lower left corner within parentheses

a: $p<0.01$; b: $p<0.05$; c: Not significant; BMI: Body mass index; HdC: Head circumference; NC: Neck circumference; ChC: Chest circumference; WC: Waist circumference; HC: Hip circumference; WHR: Waist-to-hip ratio; WHR: Waist-to-height ratio; MUAC: Mid-upper-arm circumference; WrC: Wrist circumference.

Table 2. Anthropometric values of studied subjects by age-group and gender.

Age groups	Boys (n=5593) mean ± SD	Girls (n=5189) mean ± SD	Age groups	Boys (n=5593) mean ± SD	Girls (n=5189) mean ± SD
	Height(cm)[ab]			*WC(cm)*[ab]	
2-5[c]	108.90 ± 8.50	107.17 ± 8.41	2-5	50.59 ± 5.19	50.38 ± 5.80
6-12[c]	134.60 ± 11.59	130.33 ± 11.44	6-12[c]	58.38 ± 8.02	56.81 ± 8.08
13-19[c]	159.16 ± 10.75	152.39 ± 8.97	13-19[c]	69.22 ± 8.63	66.51 ± 8.02
Total[c]	142.54 ± 19.56	133.00 ± 18.41	Total[c]	62.24 ± 10.32	58.61 ± 9.58
	Weight(kg)[ab]			*HC(cm)*[ab]	
2-5[c]	17.52 ± 3.79	16.75 ± 3.38	2-5	52.45 ± 4.47	52.45 ± 4.59
6-12[c]	28.87 ± 7.45	27.45 ± 7.68	6-12[c]	64.24 ± 7.67	62.16 ± 7.64
13-19[c]	46.13 ± 10.14	43.32 ± 8.24	13-19	77.15 ± 7.79	76.70 ± 8.53
Total[c]	35.13 ± 13.17	30.33 ± 11.83	Total[c]	68.58 ± 11.06	64.85 ± 11.37
	BMI(kg/m^2)[ab]			*WHR(cm)*[ab]	
2-5	14.68 ± 2.09	14.52 ± 2.11	2-5	0.97 ± 0.09	0.96 ± 0.10
6-12[c]	15.72 ± 2.42	15.89 ± 2.56	6-12	0.91 ± 0.09	0.92 ± 0.09
13-19[c]	18.03 ± 2.64	18.52 ± 2.62	13-19[c]	0.90 ± 0.09	0.87 ± 0.09
Total[c]	16.60 ± 2.79	16.44 ± 2.89	Total	0.91 ± 0.10	0.91 ± 0.10
	HdC(cm)[ab]			*WHtR(cm)*[ab]	
2-5[c]	48.89 ± 1.69	48.27 ± 1.81	2-5[c]	0.47 ± 0.05	0.47 ± 0.06
6-12[c]	50.77 ± 1.79	50.54 ± 2.00	6-12	0.43 ± 0.05	0.43 ± 0.05
13-19	52.71 ± 1.76	52.64 ± 1.88	13-19	0.44 ± 0.05	0.44 ± 0.05
Total[c]	51.41 ± 2.17	50.78 ± 2.43	Total[c]	0.44 ± 0.05	0.44 ± 0.05
	NC(cm)[ab]			*MUAC(cm)*[ab]	
2-5[c]	23.76 ± 1.74	23.17 ± 1.67	2-5[c]	15.22 ± 1.51	14.97 ± 1.48
6-12[c]	25.63 ± 2.07	25.38 ± 2.27	6-12[c]	17.39 ± 2.33	17.19 ± 2.27
13-19[c]	29.38 ± 2.53	28.72 ± 2.31	13-19[c]	20.83 ± 2.59	20.62 ± 2.67
Total[c]	27.05 ± 3.08	26.00 ± 2.94	Total[c]	18.65 ± 3.11	17.84 ± 3.03
	ChC(cm)[ab]			*WrC(cm)*[ab]	
2-5[c]	52.27 ± 3.68	51.38 ± 3.80	2-5[c]	11.48 ± 1.17	11.30 ± 1.09
6-12[c]	61.08 ± 6.56	58.90 ± 6.43	6-12[c]	12.92 ± 1.43	12.47 ± 1.35
13-19[c]	72.25 ± 7.91	70.02 ± 7.26	13-19[c]	14.88 ± 1.42	14.10 ± 1.33
Total[c]	64.98 ± 9.73	60.94 ± 9.11	Total[c]	13.61 ± 1.83	12.76 ± 1.63

[a] Significant difference between age range in boys ($p<0.05$) (ANOVA)

[b] Significant difference between age range in girls ($p<0.05$); (ANOVA)

[c] Significant difference between boys and girls ($p<0.05$); (t-test)

SD: Standard Deviation; BMI: Body Mass Index; HdC: Head circumference; NC: Neck circumference; ChC: Chest circumference; WC: Waist circumference; HC: Hip circumference; WHR: Waist-to-hip ratio; WHR: Waist-to-height ratio; MUAC: Mid-upper-arm circumference; WrC: Wrist circumference.

Among various anthropometric characteristics of girls, the weaker correlation were observed in the youngest age-group and increased to maximum between 6 to 12 years. Thereafter, the correlation decreased for the older age group i.e. 13-19 years. The correlation between various anthropometric characteristics of boys increased with increase in age. The age and gender-specific mean comparison

of anthropometric characteristics were presented in Table 2. The results revealed that mean of the all anthropometrics characteristics (except WHR and WHtR) increased with growth of age in both boys and girls. One-way ANOVA results showed that the means of all the stated anthropometrics characteristics were significantly different in both genders ($p<0.05$) for different age groups. On the other hand, the gender comparisons also showed that boys had significantly higher mean values in various age-groups than those of girls had with few exceptions.

DISCUSSION

In Pakistan, this study was the first of its kind that discussing how BMI and other anthropometric indicators of weight status associated during different ages. In this study, BMI of both sexes had a strong positive correlation with MUAC over different age-groups. These finding were in line with the previous reported studies[8,11] but not for Pakistan, that showed that MUAC could be served as an easy way to determine overweight and obesity in children and adolescents.

It is notable that in older boys (13-19 years), BMI also had a strong positive correlation with other traditional anthropometric parameters (NC, WC and HC) used to describe the fat pattern. This result is consistent with a recent findings[8] in the Nigerian boys, aged 13-19. While, girl's BMI had a good positive correlation with these anthropometric parameters in 6-12 year age category. Furthermore, relatively weaker correlation was observed between BMI and WHR in all age-groups for both boys and girls.

For both boys and girls, all the anthropometric measures (except WHR and WHtR) tend to increase with age and boys have more mean values in various age-groups than girls. These findings are consistent to the earlier work reported by Lu et al.[11] and Ferretti et al.[12] which showed that mean values of anthropometric measures for boys in various age-groups were larger than for girls with few exceptions.

CONCLUSION

The gender-wise mean comparisons of different anthropometric measures showed that boys had higher mean values in various age-groups than those of girls had with few exceptions. Some considerable interrelationship was seen among different anthropometric measures in boys and girls of aged 2 to 19 years. The correlation between BMI and all other anthropometric parameters were weaker in the youngest age-group except WHR. The correlation between BMI and other traditional anthropometric parameters (i.e., MUAC, NC, WC and HC) used to describe the adiposity in children were strong and positive. The BMI correlates weakest with WHR, while strongest with MUAC in all age-groups for both sexes and MUAC therefore could be proposed as a simple and convenient index and the best proxy measure in place of BMI for determining the overweight and obesity status of children and adolescents.

Conception and design: Muhammad Asif, Aslam Muhammad
Collection and assembly of data: Muhammad Asif
Analysis and interpretation of the data: Muhammad Asif, Sajid Mustafa
Drafting of the article: Muhammad Asif, Aslam Muhammad, Saima Altaf
Critical revision of the article for important intellectual content: Saima Altaf, Sajid Mustafa
Statistical expertise: Aslam Muhammad
Final approval and guarantor of the article: Muhammad Asif, Aslam Muhammad
Corresponding author email: Aslam Muhammad: aslamasadi@bzu.edu.pk
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