COMPARISON OF ANTHROPOMETRIC INDICES AS CORRELATES OF OBESITY AND HYPERTENSION AMONG AN ADULT POPULATION IN THE KATHMANDU DISTRICT, NEPAL

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ABSTRACT

Epidemiological studies utilizing newer anthropometric indices may help to assess adiposity and the associated risk. This study compared the performance of body mass index (BMI) (WHO, Asian criteria), body adiposity index (BAI), waist circumference (WC), waist to hip ratio (WHR) and waist to height ratio (WHtR) in the assessment of obesity and hypertension. Cross-sectional, observational surveys were carried out among adults (≥20 years) in randomly selected communities in the Kathmandu district, Nepal using a modified WHO STEPS instrument. The correlation, potential predictor value and performance of the anthropometric indices was determined by statistical analysis. Among 433 study respondents, prevalence of obesity (≥27.5 kg/m2) and hypertension was 24.60% and 31.18% respectively. Prevalence of central obesity using WC and WHtR criteria for Asian population was 56.35% and 71.13% respectively. The Pearson's coefficient (r) was 0.76 for WHtR, 0.67 for WC, 0.22 for WHR and 0.70 for BAI ($p < 0.0001$) with BMI. Correlation of the studied indices with systolic blood pressure (SBP) (r 0.33 - 0.41; $p < 0.001$) and diastolic blood pressure (DBP) (r 0.22 - 0.31; $p < 0.001$) was lower. Receiver operator characteristic (ROC) curve area for BAI, WC, WHR and WHtR was 0.87, 0.83, 0.58 and 0.88 for the identification of obese persons as compared to 0.58, 0.61, 0.58 and 0.63 for identification of persons with hypertension. BAI, WC and WHtR were better correlates of obesity than WHR. WHtR, WC and BMI had a higher correlation with SBP and DBP than WHR and BAI. The adjusted odds of hypertension among the obese (BMI ≥ 27.5 kg/m2) was 3.24 (95% CI 1.75, 6.01; $p < 0.0001$). Anthropometric assessment utilizing the population specific BMI (Asian criteria), WHtR and WC may be better than WHO BMI criteria in the screening for hypertension in our community-based setting. The role of the WHtR and WC as potential predictors of hypertension in the Nepalese population needs to be explored.

KEYWORDS

Body Mass Index, Body Adiposity Index, hypertension, obesity, Waist circumference, Waist to height ratio, Waist to Hip Ratio,

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INTRODUCTION

In community based epidemiological studies, anthropometric assessment is the widely used method for measuring adiposity. Measures of height, weight, waist and hip circumference help to estimate the body mass size, percentage of body fat and pattern of adiposity.[1, 2] While estimates of average body fat content in 'normal weight' persons have been derived, the percentage of body fat and pattern of fat distribution appears to differ across populations and ethnic groups.[3] The capacity of the body fat depots to store and release fatty acids and adipocytokines may contribute to the cardio-metabolic risk associated with adiposity. [4]

The body mass index (BMI), a ratio of weight in kilograms by the height in metres squared is a simple estimate of fat mass. It is the most commonly used anthropometric index to enable the classification of overweight and obese persons.[5] However, the BMI is a measure of general adiposity and cannot discriminate between lean body mass and fat mass. Hence the body fat distribution cannot be ascertained through BMI alone.[6] The current WHO adult BMI classification uses cut-offs of 25 kg/m^2 and 30 kg/m^2 to define overweight and obesity. The increasing prevalence of type 2 diabetes and cardiovascular risk factors among persons of Asian origin whose average BMI is below the cut-off points in the current WHO classification has led to the development of suggested Asia specific cut-offs for BMI of 23 kg/m^2 and 27.5 kg/m^2 for overweight and obesity respectively. [6,7]

An increase in the abdominal adipose tissue (central adiposity) has been recognised as an independent risk factor for cardiovascular disease, hypertension and type 2 diabetes mellitus. Thus, anthropometric indices such as waist circumference (WC) and waist to hip ratio (WHR) can provide information on the pattern of body fat distribution and the associated risk. [5]

Newer anthropometric indices such as the waist to height ratio and the body adiposity index have been devised to assess adiposity. Evidence from a systematic review suggests that the waist to height ratio (WHtR), a ratio of the waist circumference to the height may be useful to identify the risk of hypertension and diabetes in adults.[8]

The 'body adiposity index' (BAI) has been proposed as an alternative measure of general adiposity. It is the ratio of the hip circumference to height and can be used to estimate the percentage body fat directly.[9]

While higher rates of obesity have been reported among high- and middle-income countries, a national STEPS surveillance study in Nepal (2013) reported an overall prevalence of overweight and obesity of about 21% using the WHO BMI criteria and a 25.7% prevalence of hypertension. [10,11]

Community level data which use more precise methods for estimation may help to monitor the trends of adiposity and its associated risks and enable community-based screening and efforts for corrective actions.[12]

This study compared the performance of body mass index (WHO, Asian criteria), body adiposity index (BAI), waist circumference (WC), waist to hip ratio (WHR) and waist to height ratio (WHtR) in the assessment of obesity and hypertension among an adult population in selected rural and urban areas in the Kathmandu district.

MATERIALS AND METHODS

Cross-sectional, observational surveys were carried out among adults who were 20 years old or more in the Bajrayogini, Pukulachi, Gagalphedi and Moolpani areas in the Kathmandu district. Data collection was carried out from December 2013 to January 2017 through four such surveys, each carried out over a five-day period.

Assuming a baseline prevalence of overweight and obesity of 21%, a 5% margin of error, a 10% non-response rate and 1.5 for design effect (systematic random sampling), the minimum sample size was calculated to be 419 adults. A total of 447 adults were included in the study population after obtaining due consent. During data entry, 14 proformas were found to have missing data for one or more anthropometric variables and were excluded from the study. Four hundred and thirty-three respondents for whom there was complete and accurate data were included as the final sample size.

Sampling technique: Using systematic random sampling, every 5th household was included in the survey. A total of 230 households were surveyed and adults who were present in the household were interviewed using the modified WHO STEPS instrument after obtaining due consent.[13]

STEP1: Demographic and selected behavioural information was collected by questionnaire.

STEP 2: Physical measurement of weight, height, waist circumference, hip circumference and blood pressure was carried out by trained medical students supervised by medical doctors.

The weight was measured with a weighing scale that was placed on a hard, flat surface without slippers and reported in kilograms (kg).

The height was measured by placing the person against a wall and marking the height by a ruler. The height was measured using a non-stretchable measuring tape on the rigid wall surface and reported in centimetres (cm).

The waist circumference was measured midway between the lower most margin of the ribs and the top

of the iliac crest and reported in centimetres (cm).

The hip circumference was measured at the maximum gluteal circumference, with the person standing and the feet placed together and reported in centimetres (cm).[13]

The blood pressure measurements were taken in a seated position and on the right arm by a standardized procedure which used regularly calibrated aneroid sphygmomanometers with appropriate-sized cuffs. The systolic blood pressure was measured at the first appearance of a pulse sound and the diastolic blood pressure at the disappearance of the pulse sound.[13]

Hypertension was defined using JNC 7 criteria of systolic blood pressure (SBP) ≥ 140 mm Hg and/or a diastolic blood pressure (DBP) ≥ 90 mm Hg. Persons with SBP < 120 mmHg and DBP < 80 mm Hg were labelled as 'Normotensives'. Persons with SBP > 120 and < 140 mmHg or DBP > 80 and < 90 mmHg were labelled as 'Prehypertensive'. Persons who were previously diagnosed by a doctor or on anti-hypertensive medication were labelled as 'diagnosed hypertension'. Persons with hypertension were further classified as Stage 1 if SBP ≥ 140 and < 160 mmHg or DBP ≥ 90 and <100 and those with higher SBP or DBP as Stage 2.[14]

BMI was calculated using the Quetelet's formula by dividing the person's weight in kilograms by height in metres squared (kg/m^2). BMI cut-offs of ≥25 kg/m^2 and ≥30 kg/m^2 were used as the criteria for defining overweight and obesity according to the WHO classification.[4]

BMI cut-offs of ≥23 kg/m^2 and ≥27.5 kg/m^2 were used as the criteria for defining overweight and obesity according to Asian specific criteria.[6]

Central obesity was characterized as the waist circumference cut-off of ≥ 90 cm for males and ≥ 80 cm for females. The Waist-Hip Ratio (WHR) was calculated by dividing the waist circumference by the hip circumference in centimetres. A cut-off of WHR ≥ 1 was used for defining central obesity and increased risk among males and WHR ≥ 0.85 for females.[5]

The waist to height ratio (WHtR) was calculated by dividing waist circumference by standing height in centimetres. A cut-off of WHtR > 0.5 was used to define central obesity and cardiometabolic risk among both the sexes.[15]

The body adiposity index (BAI) was calculated as hip circumference in centimetres divided by height in meters to the 1.5 power minus 18.[9]

Ethical clearance was obtained from the Nepal Medical College Institutional Review Committee.

Data Analysis: The collected data was entered in EPI-INFO version 7.2.01 and analysed using both epi-info 7.2.01 and Stata 15IC licensed software. The categorical data was analysed by 2 X 2 and row by column tables, statistical analysis was carried out by using the Chi-square test and the Chi-square p values were reported. Prevalence rates were reported with 95% confidence intervals. The quantitative variables such as age, anthropometric indices and blood pressure levels which were found to be normally distributed were reported as means with the standard deviation. The difference between the obese and non-obese and hypertensive and non-hypertensive groups was tested by the independent t test. The mean difference between the groups was reported with the 95% confidence intervals and p value with the level of significance set at 0.05 (alpha). The study outcomes were reported with stratification for gender and age categories. Linear regression analysis was carried out to study the co-relation and potential predictor value between the systolic blood pressure, diastolic blood pressure, age and the anthropometric variables. The regression co-efficient value (β), 95% confidence intervals, correlation coefficient (r), co-efficient of determination (r^2) and p values were reported. Scatterplot matrix was plotted to depict the co-relation between the anthropometric variables and body mass index. Logistic regression analysis was carried out to estimate the odds of hypertension among the obese and overweight categories after adjustment for age sex, smoking status and alcohol use.

The receiver operating characteristic (ROC) curve was constructed as the sensitivity (true positives) versus the 1-specificity (false positives) of the anthropometric indices. The area under the curve (AUC) was calculated to assess the performance of the anthropometric indices to classify persons as obese (BMI ≥ 27.5 kg/m^2) or non-obese and as hypertensive (SBP ≥ 140 or DBP ≥ 90 mmHg) or non-hypertensive. The ROC areas were used to compare the performance of the different indices.[16]

RESULTS

Baseline characteristics (Table 1): Among the 433 adults who were included in the study 271 (62.58 %) were women and 162 (36.19%) were men. About one fourth of the study population were more than 60 years of age, 22.40% were between 40-49 years, 18.01% were between 30-39 years of age, 17.55% were between 20-29 years of age and 16.39% were between 50-59 years of age. A majority (82.21%) were married, 10.39% were widowed and 6.69% were never married. About two thirds of the study population 276 (63.74%) were from a rural community and one third 157 (36.25%) were from an urban community. About one third 158 (36.48%) were employed in agriculture and one third 156 (36.02%) were homemakers. The prevalence of smoking and alcohol use was 16.39% and 18.47% among the study population. Daily consumption of fruits was reported by 14.78% of the study population. About one half (50.11%) consumed fruits on 1 to 2 days a week. There was a significant association of obesity (BMI ≥ 27.5 kg/m^2) with gender (p <0.05) and occupational status (p<0.05). Age, cigarette smoking, alcohol use and fruit consumption pattern was significantly associated with prevalence of hypertension (SBP ≥ 140 mmHg or

Table 1: Baseline characteristics (n = 433) categorized by obesity (BMI >=27.5 kg/m2) and hypertension (140/90 mmHg) status

Variable	n (%)	Obese (%) (n = 106)	Non-obese (%) (n = 327)	Chi-square p value	Hypertensive (%) (n=137)	Non-hypertensive (%) n=296	Chi-square p value
Age (years)							
20-29	76 (17.55)	12 (15.79)	64 (84.21)	0.267	7 (9.21)	69 (90.79)	0.000
30-39	78 (18.01)	25 (32.05)	53 (67.94)		15 (19.23)	63 (80.76)	
40-49	97 (22.40)	27 (27.83)	70 (72.16)		28 (28.86)	69 (71.13)	
50-59	71 (16.39)	18 (25.35)	53 (74.65)		40 (56.33)	31 (43.66)	
60-69	61 (14.08)	13 (21.31)	48 (78.69)		27 (44.26)	34 (54.74)	
≥70	50 (11.54)	11 (22)	39 (78.0)		20 (40.0)	30 (60.0)	
Gender							
Female	271 (62.58)	76 (28.04)	195 (71.95)	0.026	82 (30.26)	189 (69.74)	0.424
Male	162 (37.41)	30 (18.52)	132 (81.48)		55 (33.95)	107 (66.04)	
Marital Status							
Currently married	356 (82.21)	92 (25.84)	264 (74.15)	0.27	115 (32.30)	241 (67.69)	0.004
Never married	29 (6.69)	4	25 (86.20)		1	28 (96.55)	
Separated/ Divorced	2 (0.46)	1	1		1	1	
Widowed	45 (10.39)	9	36 (80.00)		20 (44.44)	25 (55.55)	
Area							
Rural	276 (63.74)	63 (22.82)	213 (77.17)	0.28	90 (32.60)	186 (67.39)	0.56
Urban	157 (36.25)	43 (27.38)	114 (72.61)		47 (29.93)	110 (70.06)	
Education							
No formal schooling	178 (41.10)	38 (21.34)	140 (78.65)	0.44	68 (38.20)	110 (61.79)	0.12
Primary completed	76 (17.55)	29 (38.15)	61 (80.26)		30 (39.47)	46 (60.52)	
Secondary completed	60 (13.85)	18 (30.0)	42 (70.0)		16 (26.67)	44 (73.33)	
Higher secondary	54 (12.47)	11 (20.37)	43 (79.62)		10 (18.52)	44 (81.48)	
College	37 (8.54)	7	30 (81.08)		9	28 (75.67)	
PG	13 (3.00)	3	10		4	9	
Occupation							
Agricultural	158 (36.48)	31 (19.62)	127 (80.37)	0.04	47 (29.74)	111 (70.25)	0.213
HM	156 (36.02)	51 (32.69)	105 (67.30)		50 (32.05)	106 (67.94)	
Pvt / Govt Job	48 (11.08)	9	39 (81.25)		17 (35.41)	31 (64.58)	
Student	14 (3.23)	1	13 (92.85)		0	14 (100)	
SE	31 (7.15)	7	24 (77.41)		13 (41.93)	18 (58.06)	
Retired/ UE	26 (6.0)	7	19 (73.07)		10	16 (61.53)	

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Smoking							
Current smoker	71 (16.39)	8 (11.26)	63 (88.73)	0.005	32 (45.07)	39 (54.92)	0.008
Past smoker	11 (2.54)	1	10 (90.0)		1	10 (90.0)	
Never smoker	351 (81.06)	97 (27.07)	254 (72.92)		104 (28.72)	247 (68.23)	
Alcohol use							
Ever user	80 (18.47)	21 (24.0)	59 (76.0)	0.91	39 (48.75)	41 (51.25)	0.000
Never user	353 (81.52)	85 (24.36)	268 (75.63)		98 (27.84)	255 (72.15)	
Fruit consumption							
1 to 2 days	217 (50.11)	42 (19.35)	175 (80.64)	0.087	66 (30.41)	151 (69.58)	0.001
3 to 4 days	121 (27.94)	34 (28.09)	87 (71.90)		40 (33.05)	81 (66.94)	
5 to 6 days	16 (3.69)	7 (43.75)	9 (56.25)		10 (62.50)	6 (37.50)	
Daily	64 (14.78)	19 (29.68)	45 (70.31)		12 (18.75)	52 (81.25)	
Never	15 (3.46)	4 (26.66)	11 (73.33)		9 (60.0)	6 (40.0)	

(PG Postgraduate, HM Homemaker, SE Self-employed, UE Unemployed)

Table 2: Mean values of age, anthropometric indices, systolic and diastolic blood pressure categorized by gender

Variable	Mean (n=433) (SD)	Mean (Female) (n= 271) (SD)	Mean (Male) (n = 162) (SD)	MD (95% CI)	Independent t test p value
Age	47.24 (±16.80)	45.48 (±16.59)	50.17 (±16.77)	4.68 (1.42 - 7.93)	0.004
Weight (kg)	58.64 (±11.94)	55.68 (±11.30)	63.58 (±11.35)	7.90 (5.68 - 10.11)	0.000
Height (cm)	154.55 (±9.75)	149.93 (±7.77)	162.27 (±7.61)	12.33 (10.82 - 13.84)	0.000
BMI (kgm2)	24.55 (±4.60)	24.79 (±4.89)	24.16 (±4.05)	0.63 (0.26 - 1.53)	0.16
BAI (%)	23.19 (±4.96)	24.74 (±5.10)	20.61 (±3.41)	4.13 (3.24 - 5.02)	0.000
WC (cm)	85.90 (±12.01)	84.38 (±12.35)	88.45 (±10.98)	4.06 (1.74 - 6.37)	0.000
HC (cm)	95.15 (±9.99)	95.93 (±10.90)	93.84 (±8.12)	2.08 (0.13- 4.02)	0.03
WHR	0.90 (±0.07)	0.87 (±0.07)	0.94 (±0.94)	0.06 (0.04 -0.07)	0.000
WHtR	0.55 (±0.07)	0.56 (±0.08)	0.54 (±0.06)	0.01 (0.002 - 0.033)	0.02
SBP	123.23 (±14.99)	121.04 (±14.74)	126.89 (±14.7)	5.84 (2.96 - 8.72)	0.000
DBP	79.49 (±10.47)	78.75 (±10.44)	80.73 (±10.43)	1.98 (0.05-4.02)	0.05

DBP ≥ 90 mmHg) in the study population. (Table 1)

The mean age was significantly higher for men as compared to the women (50.17 ±16.77 years vs 45.48 ±16.59 years, p = 0.004). The mean weight (63.58 ±11.35 kg vs 55.68 ±11.30 kg) and mean height values (162.27 ± 7.61 cm vs 149.93 ±7.77 cm) were significantly higher for men as compared to women (p < 0.0001). The mean BMI was similar among the sexes (24.79 ± 4.89 kg/m^2 for women and 24.16 ±4.05 kg/m^2 for men) The average body fat percentage as measured by the BAI varied from 19.69% to 29.84% among women and 17.2% to 24.02% among men. Mean systolic blood pressure (SBP) was higher among men as compared to women (126.89 ±14.7 mmHg vs 121.04 ±14.74 mmHg). Mean diastolic blood pressure (DBP) was 78.75 (±10.44) mmHg for women and 80.73 (±10.43) mmHg for men. (Table 2)

Mean age was similar among the obese and non-obese categories (47.20 ± 15.21 years and 47.33 ± 17.35 years). Mean BMI value was 30.72 (± 2.75) kg/m^2 for the obese and 22.53 (±3.05) kg/m^2 for the non-obese. The average body fat percentage varied from 23.96 to 32.6% as compared to 17.61% and 25.47% among the non-obese. There was a significant difference in the mean values of all the studied anthropometric indices between the obese and non-obese categories (p < 0.0001). The mean SBP and mean DBP values were significantly higher (p < 0.0001) for the obese category (128.49 ± 13.65 mmHg & 83.18 ± 11.17 mmHg) as compared to the non-obese category (121.50 ±15.01 mmHg & 78.26 ± 9.94 mmHg). (Table 3)

Classification of BMI using the WHO criteria: Among the study population (n=433), 9.3% were found to be underweight and 46.65% had normal BMI. The prevalence of overweight and obesity was 32.10% (95% CI 27.97% to 36.71%) and 12.18% (95% CI 9.44% to 15.59%). Prevalence of overweight and obesity was

Table 3: Mean values of age, anthropometric indices and blood pressure among the obese and non-obese population

Variable	Obese (n=106)	Non-obese (n=327)	Mean Difference (95% CI)	Independent t test p value
	Mean (SD)	Mean (SD)	MD (95% CI)	
Age	47.20 (±15.21)	47.33 (±17.5)	3.834 (3.66 - 3.74)	0.944
Weight (kg)	70.58 (±9.22)	54.77 (±10.00)	15.81 (13.65 -17.97)	0.000
Height (cm)	151.52 (±9.37)	155.53 (±9.68)	4.00 (1.89 - 6.12)	0.000
BMI	30.72 (±2.75)	22.53 (±3.05)	8.18 (7.53 - 8.8)	0.000
BAI	28.28 (±4.32)	21.54 (±3.93)	6.73 (5.85 - 7.62)	0.000
WC	96.49 (±10.52)	82.47 (±10.35)	14.01 (11.73 - 16.30)	0.000
HC	104.83 (±8.09)	92.01 (±8.42)	12.82 (10.98 - 14.65)	0.000
WHR	0.920 (±0.077)	0.896 (±0.074)	0.02 (0.008 - 0.04)	0.003
WHtR	0.063 (±0.067)	0.530 (±0.063)	0.1067 (0.09 - 0.12)	0.000
SBP	128.49 (± 13.65)	121.50 (±15.01)	6.9953 (3.78 - 10.21)	0.000
DBP	83.18 (±11.17)	78.26 (±9.94)	4.92 (2.68 – 7.16)	0.000

higher among women (32.47% and 14.39%) as compared to men (31.48% and 12.24%). (Table 4)

Classification of BMI using the Asian specific criteria: Applying the Asian cut-offs, the proportion of underweight persons remained unchanged. The proportion of persons with normal BMI decreased to 30.25%. The prevalence of overweight and obesity increased to 36.26% (95% CI 31.72% to 40.71%) and 24.48% (95% CI 20.78% to 28.86%). Among women, the prevalence of overweight and obesity increased to 33.95% and 28.04%. Among men the prevalence increased to 40.12% and 18.52% respectively. (Table 4)

Using the Asian criteria for BMI, about one third (32.05%) of those aged 30-39 years, 27.08% of those aged 40-49 years, 25.35% of those aged 50-59 years, 22% of those aged 70 years and above, 21.31% of those aged 60-69 years and 15.79% of those aged 20-29 years

Table 4: BMI classification using WHO adult criteria and Asian specific criteria categorized by gender

BMI Classification	BMI Categories				Statistical Test
WHO BMI	**Underweight (<18.5 kg/m2)**	**Normal weight (18.5-24.9 kg/ m2)**	**Overweight (25-29.9 kg/m2) with 95% CI**	**Obese (≥ 30 kg/ m2) with 95% CI**	**Chi square p value**
Female	25 (9.23)	119 (43.91)	88 (32.47)	39 (14.39)	0.2647
			27.07, 38.51	10.36, 19.01	NS
Male	14 (8.64)	83 (51.23)	51 (31.48)	14 (8.64)	
			24.42, 39.23	4.81, 14.07	
Total	39 (9.01)	202 (46.65)	139 (32.10)	53 (12.24)	
			27.88, 36.64	9.48, 15.66	
Asian BMI	**Underweight (<18.5 kg/m2)**	**Normal weight (18.5-22.9 kg/ m2)**	**Overweight (23-27.4 kg/m2) with 95% CI**	**Obese (≥ 27.5 kg/m2) with 95% CI**	**Chi square p value**
Female	25 (9.23)	78 (28.78)	92 (33.95)	76 (28.04)	0.1468
			28.11, 39.64	22.95, 33.94	NS
Male	14 (8.64)	53 (32.72)	65 (40.12)	30 (18.52)	
			32.51, 48.10	12.86, 25.37	
Total	39 (9.01)	131 (30.25)	157 (36.26)	106 (24.48)	
			31.72, 40.71	20.78, 28.86	

Table 5: Prevalence of central obesity categorized by the WHO and Asian BMI status

Variable	WHO BMI Status				
WC Female	**Underweight**	**Normal weight**	**Overweight**	**Obese**	**Total**
< 80 cm	23 (23.00)	65 (65.00)	10 (10.00)	2 (2.0)	100
≥ 80 cm	2 (1.17)	54 (31.58)	78 (45.61)	37 (21.64)	171
WC Male					
< 90 cm	13 (14.61)	54 (60.67)	19 (21.35)	3 (3.37)	89
≥ 90 cm	1 (1.37)	29 (39.73)	32 (43.84)	11 (15.07)	73
WHR Female	**Underweight**	**Normal weight**	**Overweight**	**Obese**	**Total**
< 0.85	12 (13.48)	49 (55.06)	21 (23.60)	7 (7.87)	89
≥ 0.85	13 (7.14)	70 (38.46)	67 (36.81)	32 (17.58)	182
WHR Male					
< 1	14 (10.070	75 (53.96)	42 (30.22)	8 (5.76)	139
≥ 1	0 (0.0)	8 (34.78)	9 (39.13)	6 (26.09)	23
WHtR Female	**Underweight**	**Normal weight**	**Overweight**	**Obese**	**Total**
≤ 0.5	22 (27.85)	52	5	(0.0)	79
>0.5	3 (1.56)	67 (34.90)	83 (43.23)	39 (20.31)	192
WHtR Male					
≤0.5	11 923.91)	26 (56.52)	9 (19.57)	0	46
>0.5	3 (2.59)	57 (49.14)	42 (36.21)	14 (12.07)	116
Variable		**Asian BMI Status**			
WC Female	Underweight	Normal weight	Overweight	Obese	Total
< 80 cm	23(23.00)	51 (51.00)	22 (22.0)	4 (4.0)	100
≥ 80 cm	2 (1.17)	27 (15.79)	70 (40.94)	72 (42.11)	171
WC Male					
< 90 cm	13 (14.61)	45 (50.56)	23 (25.84)	8 (8.99)	89
≥ 90 cm	1(1.37)	8 (10.96)	42(57.53)	22 (30.14)	73
WHR Female	**Underweight**	**Normal weight**	**Overweight**	**Obese**	**Total**
< 0.85	12 (13.48)	33 (37.08)	28 (31.46)	16 (17.98)	89
≥ 0.85	13 (7.14)	45 (24.73)	64 (35.16)	60 (32.97)	182
WHR Male					
< 1	14 (10.07)	49 (35.25)	55 (39.57)	21 (15.11)	139
≥ 1	0 (0.0)	4 (17.39)	10 (43.48)	9 (39.13)	23
WHtR Female	**Underweight**	**Normal weight**	**Overweight**	**Obese**	**Total**
≤0.5	22 (27.85)	44 (55.70)	12 (15.19)	1 (1.27)	79
>0.5	3 (1.56)	34 (17.71)	80 (41.67)	75 (39.06)	192
WHtR Male					
≤0.5	11 (23.91)	25 (54.35)	9 (19.57)	1 (2.17)	46
>0.5	3 (2.59)	28 (24.14)	56 (48.28)	29 (25.00)	116

(WC Waist circumference, WHR Waist to hip ratio, WHtR Waist to height ratio)

Table 6: Blood pressure status (JNC 7 criteria) categorized by prevalence of 'diagnosed hypertension'

Diagnosed Hypertension	Blood Pressure Status (JNC 7 criteria)				Chi-square p value
	Normal	**Prehypertension**	**Hypertension**	**Total**	
No	103 (27.25)	171 (45.24)	104 (27.51)	378	0.000
Yes	3 (5.45)	19 (34.55)	33 (60.00)	55 (12.7)	
Total	106 (24.48)	190 (43.88)	137 (31.64)	433	

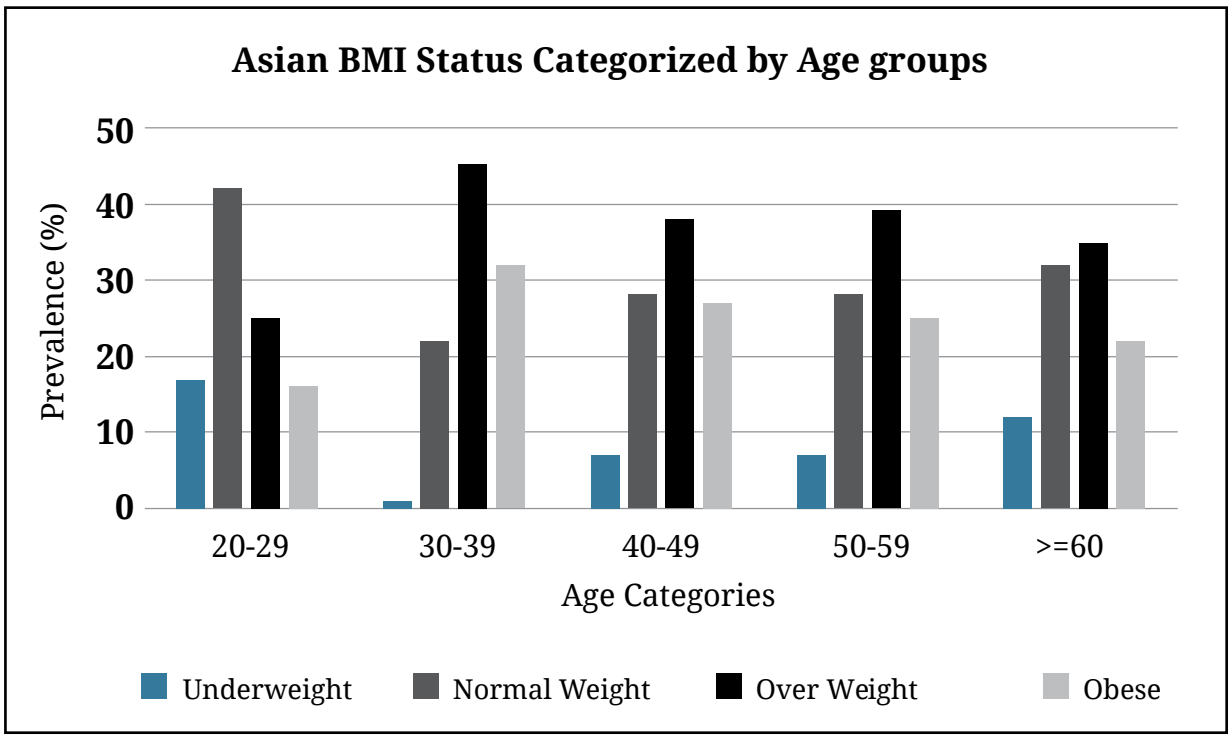

Fig 1: Asian BMI status categorized by age groups

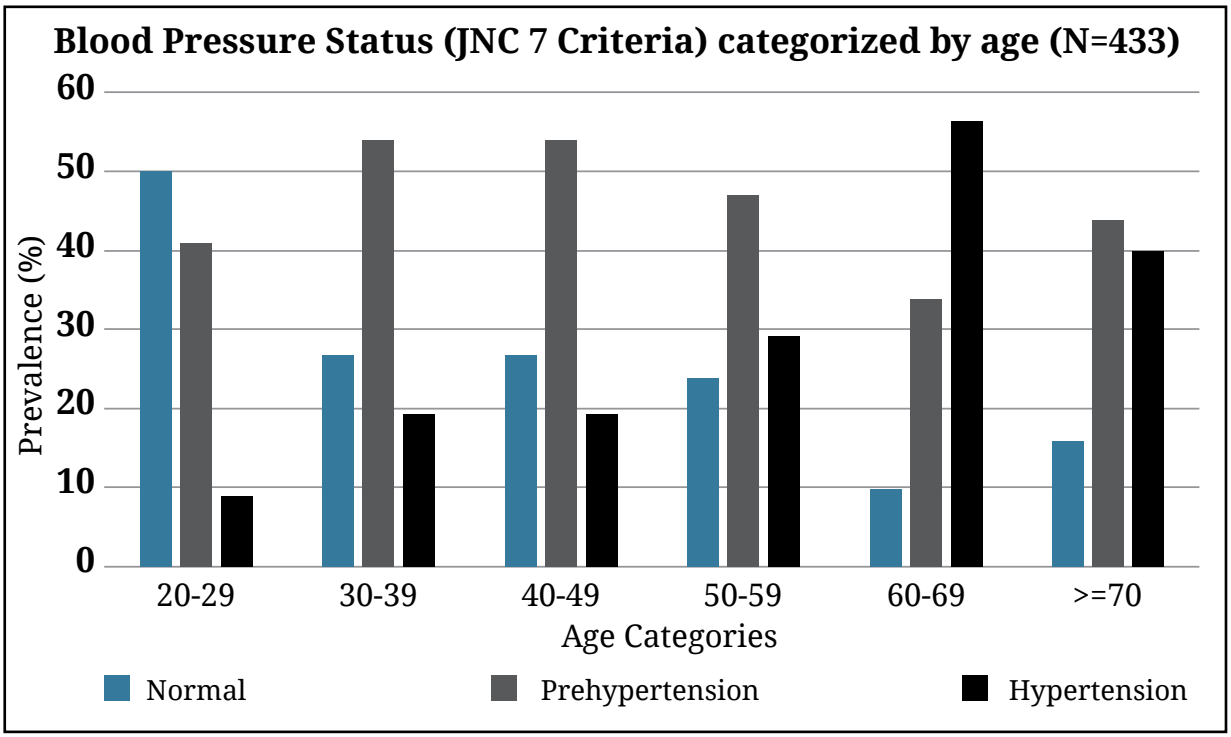

Fig 2: Blood pressure status categorized by age groups

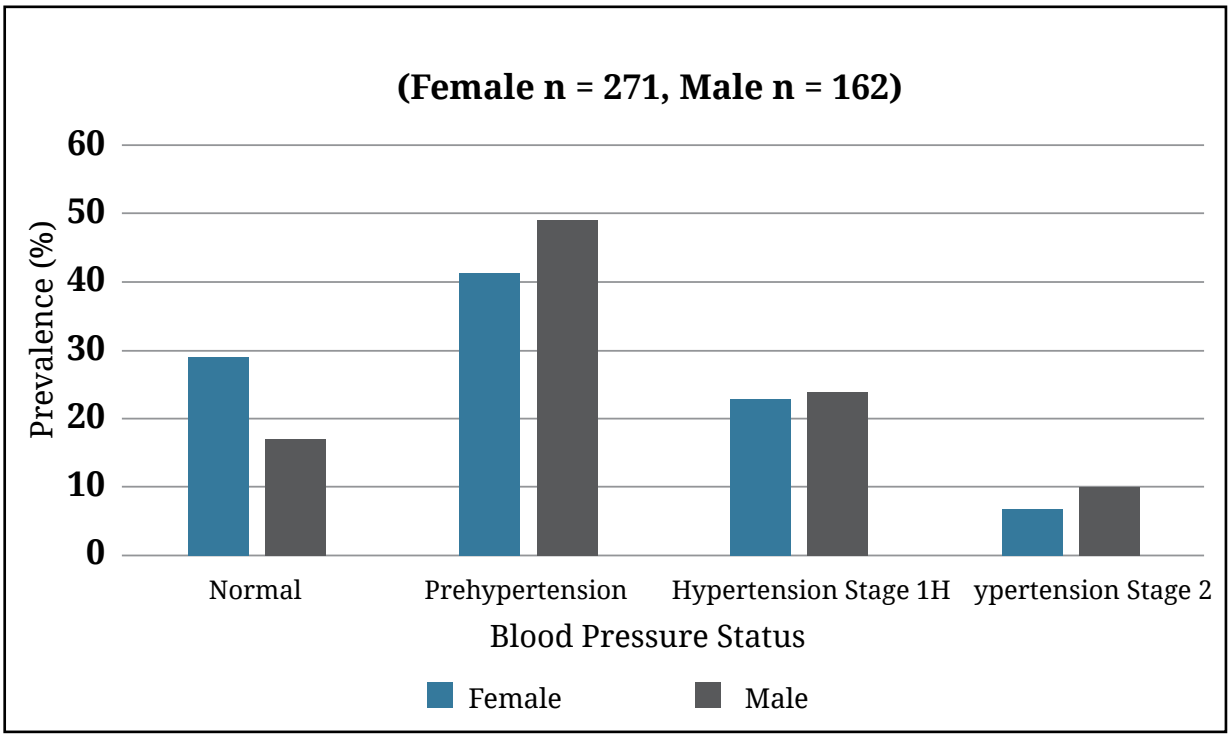

Fig 3: Blood Pressure Status categorized by gender

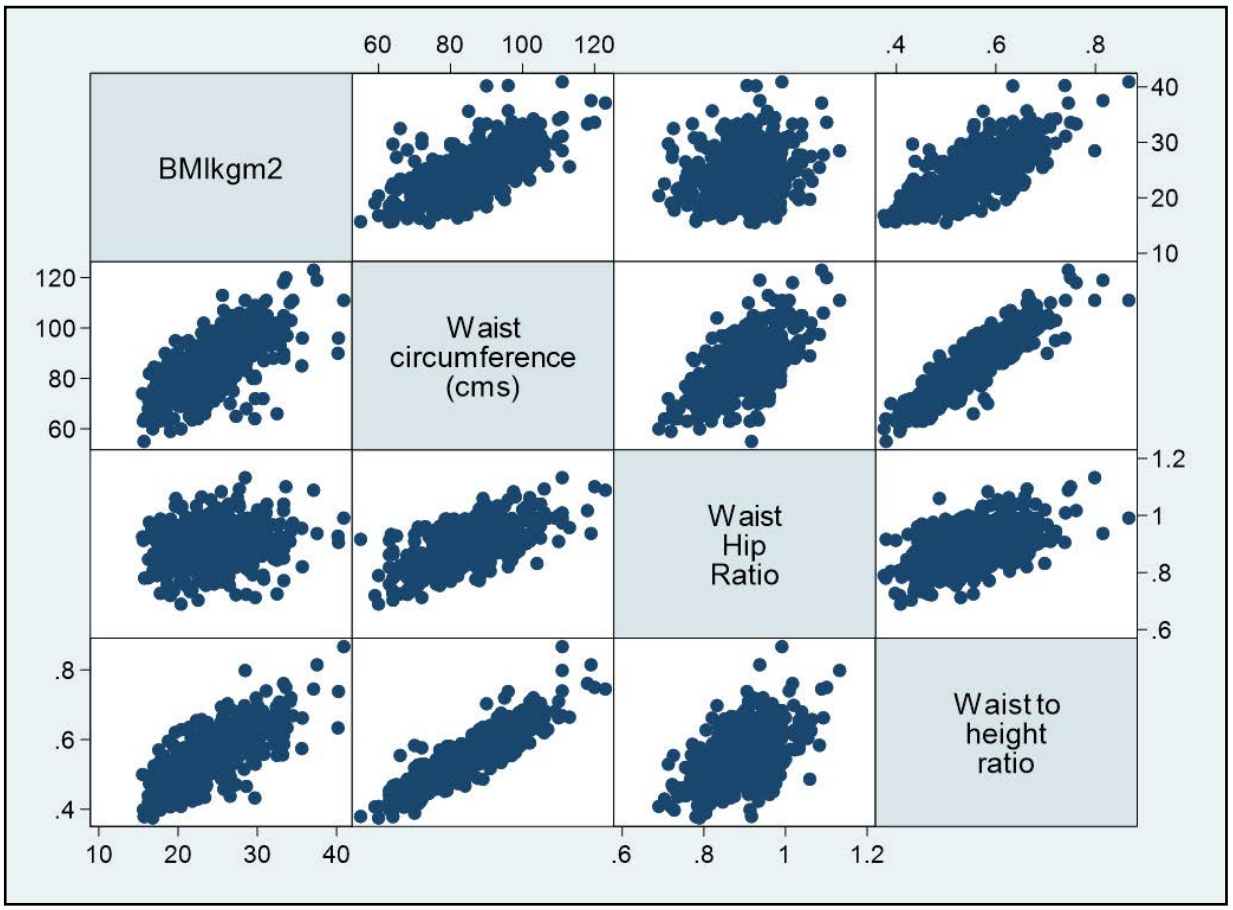

Fig 4: Scatterplot matrix for correlation between BMI and the measures of central adiposity

Table 7: Blood pressure status (JNC 7 Criteria) categorized by WHO and Asian BMI status

WHO BMI	Normal	Prehypertension	Hypertension	Sensitivity of cut-offs	Total	Chi-square p value
Underweight	18 (46.15)	11 (28.21)	10 (25.64)		39	
Normal weight	61 (30.20)	88 (43.56)	53 (26.24)		202	
Overweight	22 (15.83)	67 (48.20)	50 (35.97)	50/137 (36.49)	139	0.000
Obese	5 (9.43)	24 (45.28)	24 (45.28)	24/137 (17.51)	53	
Total	106	190	137		433	
Asian BMI	**Normal**	**Prehypertension**	**Hypertension**	**Sensitivity of cut-offs**	**Total**	**Chi-square p value**
Underweight	18 (46.15)	11 (28.21)	10 (25.64)		39	
Normal weight	43 (32.82)	58 (44.27)	30 (22.90)		131	
Overweight	33 (21.02)	73 (46.50)	51 (32.48)	51/137 (37.22)	157	0.000
Obese	12 (11.32)	48 (45.28)	46 (43.40)	46/137 (33.57)	106	
Total	106	190	137			

Table 8: Multivariate logistic regression for association between hypertension and BMI categories

Variable	OR	95% CI	p value	LR Test p value
WHO BMI				
Obese	3.10	1.56 – 6.17	0.001	
Overweight	1.80	1.09 – 2.98	0.022	
Underweight	0.99	0.42 – 2.32	0.990	
Normal weight (baseline)				0.000
Age category	1.47	1.27 – 1.71	0.000	
Sex (M/F)	0.71	0.42 – 1.19	0.198	
Smoking status (Yes/ No)	1.69	0.92 – 3.10	0.086	
Alcohol use (Yes/ No)	2.64	1.45 – 4.82	0.001	
Asian BMI				
Obese	3.24	1.75 – 6.01	0.000	
Overweight	1.88	1.06 – 3.33	0.029	
Underweight	1.24	0.50 – 3.03	0.632	
Normal weight (baseline)				0.000
Age category	1.47	1.27 – 1.70	0.000	
Sex (M/F)	0.71	0.42 – 1.19	0.199	
Smoking status (Yes/ No)	1.71	.93 – 3.14	0.082	
Alcohol use (Yes/No)	2.70	1.48 – 4.93	0.001	

(OR Odds Ratio, CI Confidence intervals, LR test Likelihood ratio test)

Table 9: Comparison of central obesity indices with the blood pressure status					
Variable	**Normal**	**Prehypertension**	**Hypertension**	**Sensitivity of cut-offs**	**Chi-square p value**
WC					
Female					
<80 cm	43 (43.00)	34 (34.00)	23 (23.00)		0.000
≥80 cm	36 (21.05)	76 (44.44)	59 (34.50)	59/82 (71.95)	
Male					
<90 cm	19 (21.35)	49 (55.06)	21 (23.60)		0.006
≥90 cm	8 (10.96)	31 (42.47)	34 (46.58)	34/ 55 (60.71)	
WHR					
Female					
<0.85	34 (38.20)	35 (39.33)	20 (22.47)		0.045
≥0.85	45 (24.73)	75 (41.21)	62 (34.07)	62/82 (60.71)	
Male					
<1	25 (17.99)	72 (51.80)	42 (30.22)		0.040
≥1	2 (8.70)	8 (34.78)	13 (56.52)	13/ 55 (23.63)	
WHtR					
Female					
≤0.5	36 (45.57)	24 (30.38)	19 (24.05)		0.000
>0.5	43 (22.40)	86 (44.79)	63 (32.81)	63/ 82 (76.82)	
Male					
≤0.5	14 (30.43)	23 (50.0)	9 (19.57)		0.003
>0.5	13 (16.67)	57 (49.14)	46 (39.66)	46/ 55 (83.63)	

Table 10: Correlation between body mass index, age and anthropometric indices					
Variable	**BMI (β)**	**r**	**r^2**	**95% CI β**	**P value**
WHtR	46.05	0.76	0.58	42.40 - 49.70	0.000
BAI	0.67	0.72	0.52	0.61 - 0.73	0.000
HC	0.32	0.70	0.50	0.29 - 0.35	0.000
WC	0.26	0.67	0.45	0.23 - 0.29	0.000
WHR	15.20	0.22	0.05	9.34 - 21.05	0.000

Table 11: Correlation between blood pressure, age and anthropometric indices										
Variable	**SBP(β)**	**r**	**r^2**	**95% CI for β**	**p value**	**DBP (β)**	**r**	**r^2**	**95% CI for β**	**p value**
BMI	0.89	0.40	0.16	0.63 -1.19	0.000	0.593	0.31	0.10	0.38 - 0.79	0.000
WC	0.35	0.41	0.17	0.24 - 0.46	0.000	0.205	0.30	0.09	0.12 - 0.28	0.000
WHR	39.47	0.34	0.12	21.03 -57.91	0.000	22.77	0.24	0.06	9.41 - 36.13	0.000
WHtR	45.27	0.37	0.14	28.04 - 62.50	0.000	27.26	0.26	0.07	14.76 - 39.76	0.000
HC	0.35	0.37	0.14	0.21 - 0.48	0.000	0.20	0.26	0.07	0.10 - 0.29	0.000
BAI	0.44	0.33	0.11	0.16 - 0.71	0.001	0.27	0.22	0.05	0.07 - 0.46	0.006

(BAI Body adiposity index, HC Hip circumference, WC Waist circumference, WHR Waist hip ratio, WHtR Waist to height ratio, β beta co-efficient, r Pearson's Corelation coefficient, r^2 coefficient of determination, 95% CI β 95% Confidence intervals for beta co-efficient)

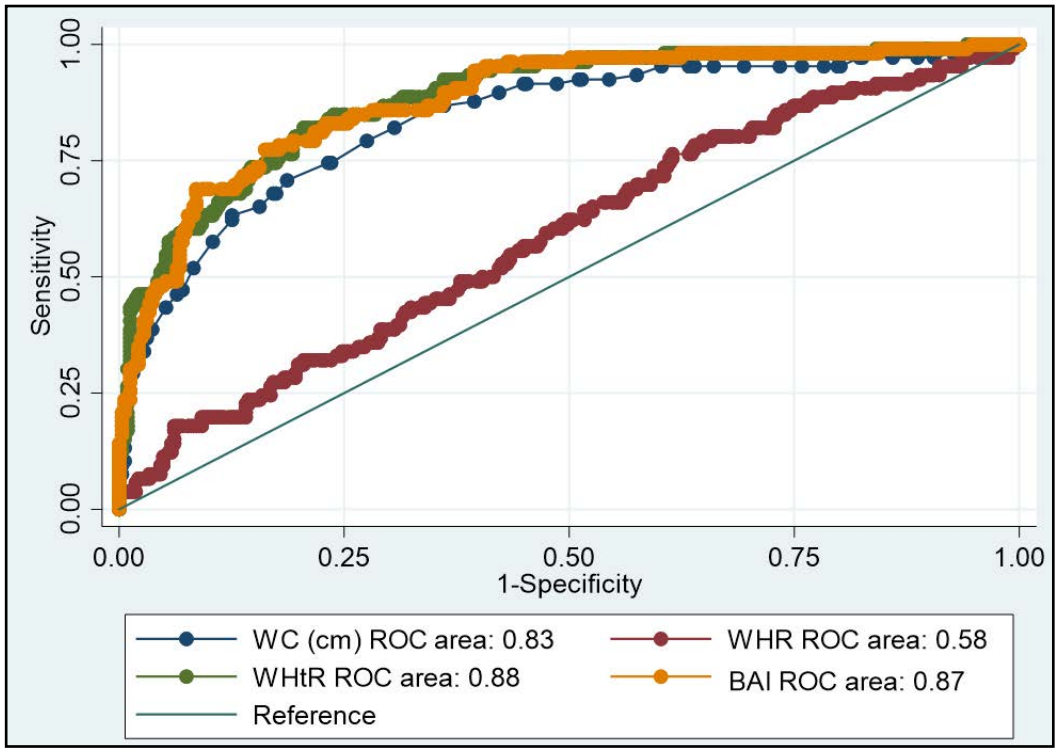

Fig 5: Comparison of ROC curve areas for performance of the anthropometric indices in the assessment of obesity

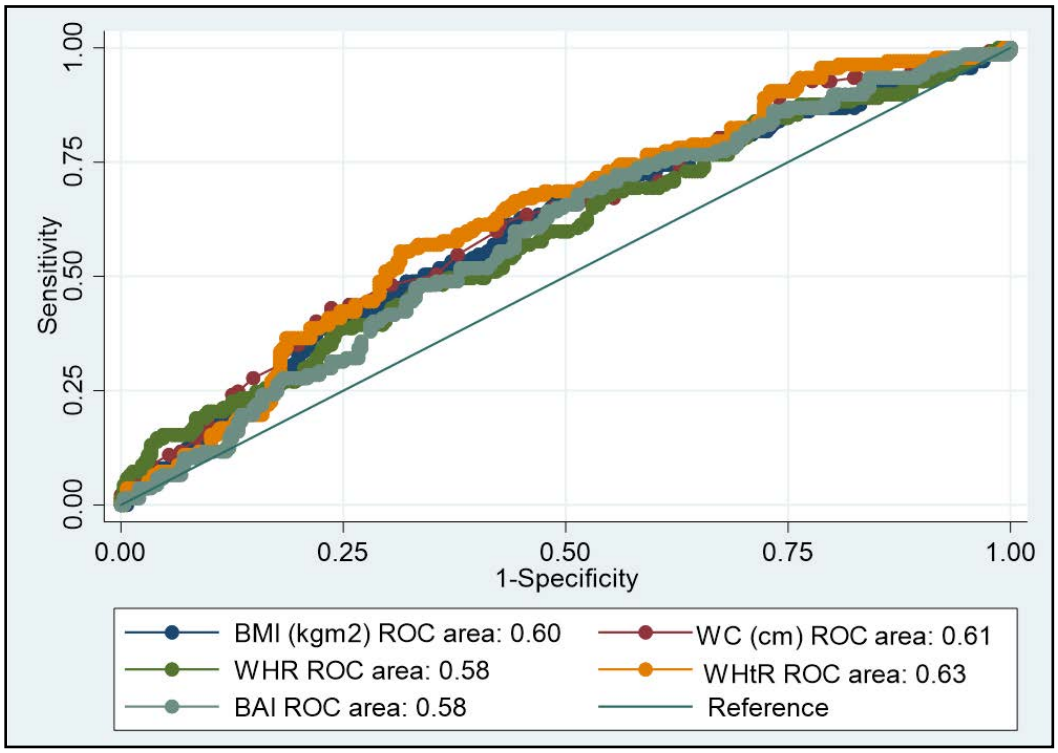

Fig. 6: Comparison of ROC curve areas for performance of the anthropometric indices in the assessment of hypertension

(BAI Body adiposity index, WC Waist circumference, WHR Waist hip ratio, WHtR Waist to height ratio, ROC Receiver operator characteristic curve)

were found to be obese.

About 44% of those aged 30-39 years, 40.98% of those aged 60-69 years, 39.44% of those aged 50-59 years, 28% of those aged 70 years or above and 25% of those aged 20-29 years were found to be overweight. (Fig 1)

The prevalence of central obesity using the waist circumference (WC), waist to hip ratio (WHR) and waist to height ratio (WHtR) criteria recommended for Asian population was 56.35%, 47.56% and 71.13% respectively. Central obesity rates were higher for women as compared to men (63.09%, 67.15% and 73.56% vs 45.06%, 14.19% and 71.60% respectively). (Table 5)

Among women with increased waist circumference (≥ 80 cm) 31.58% had normal BMI, 45.61% were overweight, 21.64% were obese and 1.17% were underweight (WHO criteria) as compared to 15.79% women with normal BMI, 40.94% overweight, 42.11% obese and 1.17% underweight using Asian criteria. Among men with increased waist circumference (≥ 90 cm) 39.73% had normal BMI, 43.84% were overweight, 15.07% were obese and 1.37% were underweight (WHO criteria) as compared to 10.96% men with normal BMI, 57.53% overweight 30.14% obese, and 1.37% underweight using Asian criteria. (Table 5)

The prevalence of hypertension was 56.35% among those aged 50-59 years, 44.26% among those aged 60-69 years age, 40.0% among those aged 70 years or more, 29.17% among those 40-49 years and 9.21% among those aged 20-29 years. (Fig 2)

The prevalence of prehypertension was 53.85% among those aged 30-39 years, 46.88% among those aged 40-49, 44% among those aged 70 years or more, 40.98% among those aged 60-69 years and 40.79% among those aged 20-29 years and 33.8% among those aged 50-59 years. (Fig 2)

About one fourth of the study population had normal blood pressure, 43.88% had prehypertension, 23.33% had Stage 1 hypertension and 7. 85% had Stage 2 hypertension. There was a significant association between the blood pressure status and gender with an increased proportion across the prehypertension, stage 1 and 2 hypertension categories among the men (chi-square 9.35, df 1, p = 0.025). (Fig 3)

The overall prevalence of prehypertension and hypertension was 44.34% (95%CI 39.28 to 48.59) and 31.18% (95% CI 27.44 to 36.17) respectively. The prevalence was higher among men as compared to women (49.38% and 33.95% vs 41.33% and 29.52%, chi-square 26.58, df 2, p < 0.001). (Table 6) (Fig 3)

The prevalence of 'diagnosed hypertension' in the study population (55/433) was 12.7% (95% CI 9.89% to 16.17%). The awareness of hypertension (33/137) was 24.08%. Among them (n =55), 96.36% were on medication, 60% had blood pressure levels more than 140/90 mmHg and 40% had levels less than 140/90 mmHg. The prevalence of undiagnosed hypertension in the study population (104/ 433) was 27.51% (95% CI 23.25 to 32.22). (Table 6)

There was a significant association between WHO BMI categories, Asian BMI categories and raised blood pressure (p<0.0001). Amongst those who were overweight (BMI ≥ 23 kg/m^2) 21.02% had normal blood pressure, 46.50% had prehypertension and 32.48% had hypertension. Amongst those who were obese (BMI ≥ 27.5 kg/m^2) 11.32% had normal blood pressure, 45.28% had prehypertension and 43.40% had hypertension. The sensitivity of WHO BMI cut-offs for identifying persons with hypertension was 36.49% (BMI ≥ 25 kg/m^2) and 17.51% (BMI ≥ 30 kg/m^2), while the sensitivity of Asian BMI cut-offs was 37.22% (BMI ≥ 23 kg/m^2) and 33.57% (BMI ≥ 27.5 kg/m^2). (Table 7)

After adjusting for age, sex, smoking status and alcohol use, the odds of hypertension among the WHO BMI obese (≥ 30 kg/m^2) was 3.10 (95% CI 1.56 to 6.17, p <0.01) and 3.24 (95% CI 1.75 to 6.01, p <0.0001) among the Asian BMI obese (≥27.5 kg/m^2) as compared to those with normal weight. (Table 8)

The sensitivity of WC cut-offs in identifying hypertension was 71.95% for women (≥ 80 cm) and 60.71% for men (≥ 90 cm). The sensitivity of WHR (≥ 85) cut-off was 60.71% for women and 23% for men (≥ 1). The sensitivity of WHtR (>0.5) cut-off was 76.82% for women and 83.63% for men. (Table 9)

On linear regression analysis all of the anthropometric indices were significantly associated with BMI (p value <0.0001). The Pearson's coefficient (r) was 0.76 for WHtR, 0.67 for WC, 0.22 for WHR and 0.72 for BAI. The coefficient of determination (r^2) was 0.58 for WHtR, 0.45 for WC, 0.05 for WHR and 0.52 for BAI after adjusting for age. (Table 10) (Fig 4)

All of the anthropometric indices were significantly associated with SBP and DBP (p value <0.0001). The Pearson's coefficient (r) with systolic blood pressure was 0.41 for WC, 0.40 for BMI, 0.37 for WHtR, 0.34 for WHR and 0.33 for BAI. The coefficient of determination (r^2) for waist circumference was 0.17, 0.16 for BMI, 0.14 for WHtR, 0.12 for WHR and 0.11 for BAI after adjusting for age. Correlation with diastolic blood pressure (DBP) (r 0.22 - 0.31; p < 0.001) was lower. (Table 11)

Comparison of ROC curve areas for discriminating between obese and non-obese persons: The AUC for WC, WHR and WHtR and BAI was 0.83, 0.58, 0.88 and 0.87 respectively. (Fig. 5)

Comparison of ROC curve areas for discriminating between persons with and without hypertension: The AUC for BMI and BAI was 0.60 and 0.58 respectively. The AUC for WC, WHR and WHtR was 0.61, 0.58, 0.63 respectively. (Fig. 6)

DISCUSSION

The present study findings reflect the burden of general adiposity, central obesity and hypertension prevalent across selected urban and rural communities in the Kathmandu district. Obesity was found to be associated with gender and occupational status while hypertension was associated with age, cigarette smoking, alcohol use and fruit consumption pattern. The rates of obesity and hypertension in the rural and urban study population were found to be similar. The adjusted odds of hypertension among the obese (BMI ≥ 27.5 kg/m^2) was about three times more as compared to those with normal weight (BMI≥ 18.5 – 23 kg/m^2).

The 2013 STEPS survey conducted in Nepal was carried out in a nationally representative sample among adults aged 15- 69 years of age (n=4079). The prevalence of overweight and obesity was reported as 17.7% and 4% respectively. Among women the prevalence was 17.3% and 4.8% respectively. Among men it was 18.0% and 3.1% respectively. The reported prevalence of hypertension was 25.7% with a higher rate among men as compared to women (28.7% vs 18.5%).[16] In comparison, the rates of overweight and obesity were higher in the present study. The mean values of all the anthropometric indices were increased as compared to the 2013 STEPS survey reported population means. The mean waist circumference was increased among women (84.38 cm vs 76.7 cm) and among men (88.45 cm vs 79.8 cm). The mean hip circumference was increased for both women (95.93cm vs 87.5 cm) and men (93.84 cm vs 88.1 cm). Similarly, the mean WHR was increased among the women (0.87 vs 0.90) and men (0.94 vs 0.90). The mean SBP was lower in the present study (123.23 mmHg vs 127.4 mmHg) while the mean DBP was similar (79.49 mmHg vs 79.8 mmHg).[11]

The overall prevalence of hypertension was higher (31.18 % vs 25.7%). When persons aged 70 years and above (n= 51) were excluded from the present study analysis, the hypertension prevalence rate remained higher at 30.63% (95% CI 26.22% to 35.42%).

Karmacharya *et al*, in a cross-sectional study among 298 persons with hypertension in Dhulikhel, Nepal reported that 43.62% were aware of their hypertensive status, 76.15% (n=130) were on treatment and about 35.3% of them had blood pressure below SBP < 140 Hg and DBP < 90 mmHg (target level).[17]

In comparison, the awareness of hypertension was much lower in the present study at about 24.08%. About 40% of those on treatment had blood pressure below the target level.

The average body fat content has been found to vary between 15% to 35% among women and between 10% to 25% among men with normal weight. [18] In the present study as well, the average body fat content (BAI) was higher among women as compared to the men. This measure of general adiposity strongly corelated with BMI but had a weak correlation with SBP and DBP.

Bergman *et al* had proposed the use of the BAI as an alternative to the BMI, to assess the body fat percentage among both the sexes in ethnic populations (African American) in the United States. The BAI was suggested for use in settings where accurate measurement of body weight may not be possible. The investigators had reported a high positive co-relation (0.8) with DEXA derived percentage body fat and concluded that BAI can directly measure the percentage body fat without the need for numerical correction across sex and ethnic groups.[9]

However, the value of the BAI as an alternative to BMI has been debated. Freedman *et al* compared the performance of BAI, BMI, WC, HC in the estimation of percentage body fat among 1151 adults and concluded that BAI was not more accurate than the other indices.[19]

A small validation study in a South Asian population (n = 80) reported that the average body fat content varied from 17.73 to 34.7 as measured by the BOD POD, an air displacement plethysmography method. The BAI showed the strongest correlation with average body fat content (r = 0.74) and the WHR had the weakest correlation (r=0.33).[20]

The China Nutrition and Health Survey (n=52621) reported an abdominal obesity (increased waist circumference) prevalence of 27.8% among men and 45.9% among women. [21]

The more recent ICMR-INDIAB phase I study reported increased prevalence rates of central obesity and general obesity from 4 states in India (26.6, 18.7, 16.9, 36.1% and 24.6, 16.6, 11.8, 31.3%).[22]

In comparison to the prevalence rate of central obesity among neighbouring countries, the prevalence rate in the present study was higher.

The performance of the waist to height ratio and waist circumference was better than the waist hip ratio in the assessment of obesity in the present study. The co-efficient of determination suggested that 45- 58% of variation in the BMI could be explained by WC and WHtR. A high positive linear correlation was seen between WHtR, WC and BMI while WHR had a moderate positive linear correlation.

The waist circumference has been proposed as a better estimate of central obesity in place of the WHR. An increased WHR could indicate either an increased waist circumference or a decreased hip circumference particularly among elderly persons.[23]

The National Health and Nutritional Examination Survey (NHANES), a large cross-sectional study in the US population (n= 12901) reported a significant correlation between the BMI, WC and WHtR. The investigators concluded that BMI, WC and WHtR may not be very accurate measures of body fat percentage but corelated well with the body fat within age-sex groups. They were also useful to distinguish categories

of percentage body fat.[24]

In a cross-sectional anthropometric study among 388 Indian Gorkha males aged 20-49 years (military personnel), the ROC AUC for BMI, WC, WHR and WHtR was 0.86, 0.82, 0.74 and 0.81. For determining obesity, the investigators recommended cut-offs of 23.4 for BMI, 77.8 cm for WC and 0.47 for WHTR for the active male Gorkha population.[25] The AUCs reported were similar with the exception of the WHR. The active male population had an improved performance by the WHR, while in the present study population with about 16% of the participants between 50-59 years of age and 25% over the age of 60 years, the WHR had a lower AUC of 0.58.

About 11-19% of the variation in the SBP and 5-10% variation in the DBP could be explained by the anthropometric indices in the present study population. WC, BMI and WHtR had higher correlation with both the parameters as compared to WHR and BAI. The marginally larger AUC for WHtR and WC suggests that their performance may be better than BMI alone for identifying persons with hypertension.

The increased sensitivity of the Asian specific cut-offs for identifying persons with hypertension suggests their utility in the screening for hypertension in the study population. Among the measures of central obesity, WHtR and WC cut-offs were more sensitive than the WHR cut-offs in the identification of hypertension among both the sexes. Moreover, the greater proportion of persons with normal BMI (WHO criteria) with an increased waist circumference as compared to those with normal BMI (Asian criteria) reflects the importance of using population specific criteria in the assessment of risk associated with adiposity.

Hsieh *et al* compared the sensitivity of BMI, WHtR and WC to identify cardiometabolic risk factors like hypertension, raised LDL, low HDL in a large study population (n= 8278). The waist to height ratio (0.5) had a higher sensitivity (74.4% to 80.5%) as compared to the BMI (>25 kg/m2) (36.3% to 43.7%) among men. Among women it was 65.6% to 82.3% as compared to 16.8% to 28.2% for waist circumference. The investigators concluded that the waist to height ratio may be useful to screen for cardiometabolic risk.[15]

A meta-analysis of cross sectional and prospective studies (n=512809) has suggested that the waist to height ratio may be better than BMI in the Asian population as compared to non-Asian populations in identifying persons at risk of hypertension (RR 0.92) or diabetes (RR 0.71). However, due to the heterogeneity of the studies included in the analysis, further investigation on the usefulness of this anthropometric index was suggested.[26]

Another large cross-sectional study among 7336 adults in China reported a higher prevalence of hypertension among men as compared to women (23% vis a vis 17%). There was a significant association with increased BMI, WC, WHtR and WHR (p for trend < 0.001). However, the investigators concluded that the measures of central obesity did not perform better than the BMI in the assessment of the risk of hypertension.[27]

In a large cross-sectional study among urban and rural residents of North India (n=3042), the waist circumference was reported to perform better than BMI, WHR and WHtR in the prediction of the metabolic syndrome (which includes raised blood pressure). However, overall a WHtR of 0.52 was found to be better than the WC regardless of gender and place of residence in the estimation of risk.[28]

The present study findings suggest that the newer anthropometric indices perform well in the assessment of obesity however their role in the assessment of hypertension needs further investigation.

Limitations of the study: The cross-sectional design of our study precludes any causal association between the anthropometric indices and the study outcomes. These associations would be preferably inferred from large longitudinal studies. The accuracy of the anthropometric indices in the measurement of percentage body fat was not assessed in our study. As with any anthropometric assessment study measurement bias is a concern. Assessment was carried out by trained medical students, using a standardized measurement procedure. The same measurement instruments were used across the study population and constant supervision was adopted to minimize the measurement bias.

In conclusion, newer anthropometric indices such as the body adiposity index, waist circumference and waist to height ratio showed a strong correlation with BMI and were better correlates of obesity than the waist to hip ratio. WHtR, WC and BMI showed a higher correlation with SBP and DBP than WHR and BAI. Anthropometric assessment utilizing the population specific BMI (Asian criteria), the waist to height ratio (WHtR) and the waist circumference (WC) may be more useful than the WHO BMI criteria in the screening for hypertension in our community-based setting. The role of the waist to height ratio and waist circumference as potential predictors of hypertension in the Nepalese population needs to be explored.

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