BMI, Waist to Height Ratio and Waist Circumference as a screening tool for Hypertension in Hospital out Patients: A Cross-Sectional, Non-inferiority study

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Abstract

Background

Obesity has become a global epidemic and an important risk factor for non-communicable diseases. Earlier thought to be a problem in the developed world, it has become a problem in low-and middle-income countries, including Nepal. In the absence of routine surveillance or a registry system, the actual burden and trend of obesity in Nepal is unknown. Obesity and overweight are recognized as risk factors for hypertension and associated with cardiovascular diseases. The study aimed to find out the burden of obesity, using three commonly employed metrics in the hospital outpatient setting of a developing country as predictors of hypertension, and compare the ability of different anthropometric measurements through a non-inferiority study to predict hypertension.

Methods

This cross-sectional study was conducted among 40-69 years outpatients in a tertiary Eye, and ENT hospital in a semi-urban area of Nepal among randomly selected 2,256 participants from 6,769 outpatients evaluated in Health Promotion and Risk Factor Screening Service. We did a correlation analysis to determine the relationship between anthropometric measurement and blood pressure. The area under the Receiver Operating Characteristic curve of Body Mass Index (BMI), Waist to Height Ratio (WHtR), and Waist Circumference (WC) was calculated and compared.

Results

The prevalence of obesity and overweight by BMI was 16.09% and 42.20%, respectively; by WHtR was 32.76%, which is two times higher than obesity measured by BMI. High WC was observed among 66.76% of participants. Female participants had a greater prevalence of high WC (77.46%) than males (53.73%) ($p<0.001$). Prevalence of hypertension and pre-hypertension was 40.67% and 36.77%, respectively. The areas under the curve were significantly higher than 0.5 for BMI (0.593), WHtR (0.602), and WC (0.610).

Conclusion

WC correlated well with obesity and hypertension. It also had a higher predicting ability than WHtR and BMI to predict hypertension. WC thus proved to be non-inferior to two other commonly used metrics. It proved superior in detecting obesity in female. This inexpensive and simple non-tension tape measurement may play an important role in future diagnosis of obesity and prediction of HTN in resource-constrained settings of developing countries.

Background

The world is rapidly becoming obese [1, 2]. According to the World Health Organization (WHO), obesity rates have tripled since 1975. In 2016, more than 1.9 billion people above 17 years were overweight, and of those, over 650 million were obese [3]. The trends in adult BMI in 200 countries showed that the age-standardized prevalence of obesity increased from 3.2% to 10.8% in men, from 6.4% to 14.9% in women from 1975 to 2014 [4]. Obesity is known to be strongly associated with hypertension (HTN), heart disease, and diabetes [5, 6]. Worldwide, 23% and 44% of Ischemic heart disease and diabetes have been reported to be associated with overweight and obesity [7]. Moreover, obesity and HTN are a significant cause of premature death worldwide [8, 9]. WHO estimated that 1.13 billion people worldwide have HTN; among them, two-thirds are living in LMICs. The rise in burden of NCDs – major killers of the world's population- (such as cardiovascular disease (CVD), diabetes, cancer, and chronic obstructive pulmonary disease) closely parallels rise with the burden of obesity [10, 11]. Most NCDs have obesity as an important risk factor [12, 13]. Recently, obesity has also been reported to be a high risk for morbidity and mortality from COVID-19 [14]. COVID-19 has also been reported to have resulted in a higher incidence of obesity [15].

Long believed to be a condition affecting affluent countries, obesity is rising even in LMICs [16-18]. Although it co-exists with malnutrition, more people die of obesity in LMICs than under-nutrition [19], which is also true for Nepal [20]. These three pandemics - obesity, under-nutrition, and climate change—represent a Global Syndemic that affects most people in every country and region worldwide [21]. If the same trend continues, the health system in LMICs would no longer support the future burden of combined onslaught of NCDs and emergent infectious diseases and the effects of climate change [22]. The fragility of LMICs to control infectious diseases has been well exposed by COVID-19 pandemic. The weak existing health systems have failed in their ability to cope with a new challenge. The emerging epidemics have put patients with NCD at greater risk of death due to the inability to access treatment. The estimated cost of obesity and NCDs to the countries has been estimated to be up to 9.3% of Gross Domestic Product (GDP) [23].

Nepal has, for long, suffered from undernutrition among its children [24]. However, recent years' overweight and obesity data show an increasing trend for obesity [25-29]. This is not entirely surprising given that the country is rapidly undergoing urbanization, change in lifestyle, and dietary pattern [25, 30]. Based on the global burden of disease data, the cause of death from NCDs in Nepal has reached 66% in 2017 from 36.1% in 2009 [31, 32]. Additionally, it is also reported that overweight, obesity, and NCDs occur more frequently among adults who have been undernourished in childhood [33, 34]. This makes children in LMICS more vulnerable to develop obesity in adult life.

Non-communicable diseases country profiles 2018 estimated NCDs account for 66% of all deaths in Nepal, in which CVD causes 30% of deaths [35]. The prevalence of HTN tripled in 25 years between 1981 and 2006 and increased to more than double in 10 years (2008 to 2019) [29, 36]. A similar trend was seen in the prevalence of overweight or obesity, which increased from 7.20% to 24.30% between 2008 to 2019

[27, 29]. The regional prevalence of HTN, overweight, and obesity in Eastern Nepal in 2011 was 34%, 28%, and 32%, respectively [37].

Like many LMICs, Nepal is battling a triple burden of diseases: communicable, NCDs, and injuries with CVDs being the most common [38]. Research done in the last decade shows that the conventional risk factors for CVDs are present in a high proportion in the Nepalese population [27]. In the absence of a routine surveillance or registry system, the actual burden and trend of CVDs in Nepal remains uncertain. Early detection of individuals at high CVD risk is the cornerstone of primary prevention. Simple routine screening methods such as measuring WHtR, WC, blood pressure (BP), which help detect CVDs, are not routinely practiced in LMICs because of heavy patient load and staff shortage.

A simple anthropometric measurement could be used to determine the risk of having hypertension. Several studies show that the different anthropometric measurements of obesity can predict CVDs risk, such as HTN, though the best anthropometric measurement as a predictor of HTN remains contentious and controversial. BMI, WC, and WHtR are commonly used anthropometric screening tools to predict HTN and other CVDs [39]. Some studies have suggested that WC and WHtR may be better predictors for HTN and CVD risk [40-45], while other studies suggest that BMI and WC as better predictors of HTN [46-48]. A meta-analysis suggested that WC is a better predictor for CVDs risks such as HTN and recommended that it should be used in clinics and research [49].

Most reported studies on obesity, HTN, and their association had been conducted in community settings. There is a paucity of hospital data on the burden of obesity, HTN, and an association between them in outpatient hospital settings of LMICs. So, this study was designed to find out burden of obesity and HTN and compare the ability of three different currently available anthropometric measurements to predict HTN in the hospital outpatients in low-income setting.

Methods

This hospital-based cross-sectional descriptive study was conducted from June to December 2019 at Hospital for Children Eye, ENT and Rehabilitation Services (CHEERS), Bhaktapur, Nepal. We used systematic random sampling to select the participants. Every third consecutive participant aged 40 to 69 visiting the Health Promotion and Risk Factor Screening (HP-RFS) service of CHEERS during the study period constituted the study population. The sample size calculation was based on hypertension's prevalence 46.7% (P) [28]. Margin of error considered as 5% (D), 95% confidence level (Z=1.96) and 80% response rate. The formulae used for sample size calculation is $N=(Z^2*P(1-P))/(D^2)$. The calculated sample size is multiplied by the number of domains to get the final sample size. The numbers of domains were decided to be two age groups and two genders. Based on the calculation, the minimum sample size required was 1,913. All participants were informed about the purpose of the screening service; informed consent was obtained before anthropometric measurements. Pregnant women and people unable to stand properly were excluded from data analysis for this study.

A standardized protocol is followed at the hospital for anthropometric measurements. A community medicine auxiliary (CMA) was trained on an existing protocol for obtaining anthropometric measurements for height, weight, WC, and BP. The height, weight, and WC were measured on a portable digital weighing scale (Equinox weighing scale), stadiometer (Prestige stadiometer), and constant tension tape, respectively. The participants were asked to remove bulky clothes, shoes, and cap before taking measurements. The WC in cm was measured at the midpoint between the lower edge of the rib cage and the iliac crest after a full expiration. BMI was calculated as weight (kg) divided by height in meter squared (m^2). The WHtR was calculated as WC in cm divided by height in cm. Besides anthropometric measurements, socio-demographic information and history of HTN (anti-HTN medication) was also enquired.

The standard value for WHtR was considered as 'no increased risk' (WHtR <0.5); 'increased risk' (WHtR ≥ 0.5 to <0.6) and 'very high-risk' (WHtR ≥0.6). Similarly, for WC, WC=90 cm for male and WC=80 cm for females was considered as 'cutoff value' [50]. The standard weight status categories associated with BMI range of 18.5 - 24.9 kg/m^2 were considered normal, whereas 25.0 to 29.9 kg/m2 and 30 kg/m2 were considered overweight and obese [51].

BP of the participants was measured by aneroid sphygmomanometer with adult cuff size. Participants were asked to sit quietly for 15 mins, leg uncrossed in a comfortable position. BP was measured in the left arm, placing the cuff at the heart level, placing the artery mark in the cuff at the level of the brachial artery. Blood pressure in participants with initial high blood pressure was re-measured after 15 minutes.

The participants were classified as hypertensive if their systolic blood pressure (SBP) was 140 mmHg or higher and/or diastolic blood pressure (DBP) was 90 mmHg or higher and pre-hypertensive (Pre-HTN) if SBP levels were between 120-139 mmHg and/or DBP levels were between 80-89 mmHg. The participants were also considered hypertensive if they were taking antihypertensive medication, even though their BP was normal at the time of measurement. The participants who did not fit in all of the above categories were considered as normotensive.

Collected data were instantly entered in Excel (MS Office 2010). Data analysis was done using R language, version 4.0.0. Continuous variables are shown as the mean, standard deviation (SD), and categorical variables as frequency and percentage. Independent sample t-test was done to compare mean values of continuous variable between different groups. We used logistic regression analysis to find the effect of socio-demographic variables, different obesity metrics separately, and adjusted odds ratio (AOR) for hypertensive compared to the non-hypertensive group was analyzed by entering age and sex in a model with socio-demographic variables in separate different analysis models. Odds ratios (OR) were also reported in 95% Confidence Interval. We calculated correlation analysis and calculated Spearman's product-moment correlation coefficient. The area under Receiver Operating Characteristic (ROC) curve of BMI, WHtR and WC on predicting hypertension with 95% confidence interval (CI) was calculated. The CI, which did not include 0.5 were considered to indicate significant results. The p-value <0.05 was considered significant for all tests.

Results

This study included 2,256 randomly selected participants from 6,769 aged 40-69 years persons visiting HP-RFS service at CHEERS from June to December 2019. The mean (SD) age of the participants was 51.75 (8.47) years. The visitors were at this specialty hospital for general eye and ENT consultations.

The mean (SD) BMI was 25.29 (3.81) kg/m^2 and 26.72 (4.44) kg/m^2 for male and female participants respectively (p<0.01). The mean BMI was observed to gradually decrease with advancing age in both male and female participants. The mean (SD) WHtR was 0.56 (0.06) and 0.58 (0.08) for male and female (p<0.01) respectively. Similarly, the mean (SD) WC was 90.96 (10.32) cm and 88.24 (10.94) cm for males and females (p<0.01) respectively.

Table 1: Mean (SD) of different anthropometric measurements according to age and gender

	Age group					Gender				
	40-54 years		55-69 years		p-value	Male		Female		p-value*
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
SBP	118.46	14.96	122.77	16.49	<0.01	121.47	15.50	118.90	15.74	<0.01
DBP	79.21	10.74	79.39	10.25	0.69	79.98	10.67	78.69	10.43	<0.01
Weight (KG)	65.55	10.81	61.58	11.41	<0.01	67.41	11.15	61.32	10.48	<0.01
Height (CM)	157.60	8.84	155.47	9.15	<0.01	163.19	7.23	151.54	6.62	<0.01
WC (CM)	89.51	10.38	89.40	11.36	0.83	90.96	10.32	88.24	10.94	<0.01
WHtR	0.57	0.07	0.58	0.08	0.02	0.56	0.06	0.58	0.08	<0.01
BMI	26.41	4.08	25.50	4.41	<0.01	25.29	3.81	26.72	4.44	<0.01

* independent sample t-test

Prevalence of Obesity and overweight

The prevalence of obesity (BMI $\geq$ 30 kg/m^2) and overweight (BMI= 25.0 to 29.9 kg/m^2) was 16.09% and 42.20% respectively. Female participants had higher prevalence of obesity (21.4%) than male (9.6%) (p-value<0.001). The observed prevalence of overweight using BMI, among maless and females, was 42.8% and 41.7%, respectively, was statistically not significant (p-value = 0.6121). Younger age groups had a significantly higher prevalence (p-value <0.001) of overweight and obesity in both genders. Table 2 summarizes obesity and overweight according to gender and age groups. The odds ratio for being obese, comparing females to males was 2.58 (95% CI:2.01-3.31), and that of being overweight was 0.95 (95% CI:0.0.81-1.13).

The prevalence of obesity by WHtR was 32.76%, which is higher than obesity measured by BMI. Female participants had a higher prevalence (40.1%) than male participants (23.8%), and the difference is statistically significant (p-value < 0.001). Age group 40 – 54 years had a significantly higher prevalence of abdominal obesity among female participants (37.59% vs 44.52%, p=0.0195), which was not different among male participants (23.96% vs 23.66%, p=0.974).

High WC was observed among 66.76% of participants; female participants had much higher prevalence (77.46%) than males (53.73%) (p<0.001). Thus, WC detected the highest prevalence of obesity compared to the other two metrics; the prevalence is not significantly different in-between age groups.

Table 2: BMI, WHtR, and WC classification according to age and sex

Characteristic		n	BMI			WHtR			WC#	
			≥ 30.0 kg/m^2	25.0 - 29.9 kg/m^2	< 25.0 kg/m^2	> 0.60	0.50 - 0.59	< 0.50	≥ cut off	< cut off
All		2,256	16.09	42.20	41.71	32.76	53.19	14.05	66.76	33.24
Male	All age	1,048	9.60	42.80	47.50	23.80	60.00	16.20	53.73	46.27
	40-54	634	10.88	47.48	41.64	23.65	60.25	16.09	55.68	44.32
	55-69	384	7.55	35.16	57.29	23.96	59.63	16.41	50.52	49.48
Female	All age	1,238	21.40	41.70	36.90	40.10	47.60	12.30	77.46	22.54
	40-54	782	21.74	44.37	33.89	37.59	50.00	12.40	77.75	22.25
	55-69	456	20.83	37.06	42.10	44.52	43.42	12.06	76.97	23.06

cut off value of WC for male is 90 cm and for female is 80 cm

Prevalence of Hypertension

The overall prevalence of HTN and pre-HTN was 40.67% and 36.77%, respectively. Male participants had a slightly higher prevalence of HTN (42.72%) than female participants (39.00%). The prevalence of HTN for both genders was found to increase as the age group increased. Prevalence of Pre-HTN was found to be 36.78% and 35.11% among male and female participants. A staggering 81.50% male and 74.11% of female participants had either established HTN or pre HTN (HTN suspects). A concerning finding was that among 916 participants with HTN, 57.4% didn’t know they had raised BP before this study.

Age-adjusted AOR for being hypertensive for females compared to males was 0.86 (95% CI:0.72-1.02), and sex sex-adjusted AOR for being hypertensive was 1.61 (95% CI: 1.35-1.91) for the age group 55-69 compared to age group 40-54.

Table 3: HTN, socio-demographic variables, and risk factors

		Pre HTN n (%)	HTN n (%)	Unadjusted Odds Ratio for HTN (95% CI)	Adjusted Odds ratio* for HTN (95% CI)
All		828 (36.77)	916 (40.67)		
Sex	Female	434 (35.11)	482 (39.00)	1	1
	Male	394 (38.78)	434 (42.72)	0.86 (0.72-1.01)	0.86(0.72-1.02)
Age group	40-54	544 (38.50)	514 (36.38)	1	1
	55-69	284 (33.85)	402 (47.91)	1.61 (1.35-1.91)	1.61(1.35-1.91)
BMI	< 25 kg/m^2	337 (35.93)	312 (33.26)	1	1
	≥ 25 kg/m^2	491 (37.37)	604 (45.97)	1.74 (1.43-2.03)	1.89 (1.58-2.26)
WHtR	< 0.5	93 (31.74)	83 (28.33)	1	1
	≥ 0.5	735 (37.52)	833 (42.52)	1.87 (1.43-2.45)	1.92 (1.46-2.52)
WC# (CM)	< cutoff	281 (37.57)	235 (31.42)	1	1
	≥ cutoff	547 (36.37)	681 (45.28)	1.81 (1.50-2.17)	2.02 (1.66-2.45)

cut off value of WC for male is 90 cm and for female is 80 cm

* AOR were adjusted for age and sex variables

Obesity and HTN

Prevalence of HTN among the participants with BMI ≥ 25 kg/m^2, WHtR ≥ 0.5, and WC ≥ cutoff value was 45.97%, 42.52%, and 45.28%, respectively. Not surprisingly, a higher prevalence of HTN was found among participants with either overweight or obesity than participants with average weight (P-value<0.001). Age and sex-adjusted AOR for being hypertensive among high BMI, WHtR, and WC than normal; were 1.89 (1.58-2.26), 1.92 (1.46-2.52), and 2.02 (1.66-2.45), respectively indicating WHtR and WC's ability to predict HTN than BMI better.

Table 4 shows the correlation between BMI, WC, WHtR, BP, and Age, including level of significance. A strong positive correlation (r=0.682, P<0.01) was found between WC and BMI. WC had highest positive correlation (r=0.188, p<0.01) with SBP than other two metrics. However, BMI had highest positive correlation (r=0.214, p<0.01) with HTN than other metrics. The relationship between all three anthropometric metrics and SBP was found higher than with DBP.

Table 4. Correlation between BMI, WHtR, WC, SBP, DBP, and Age

	BMI	WC	WHtR	SBP	DBP	Age
BMI	1	0.682**	0.770**	0.154**	0.214**	-0.120**
WC	0.682**	1	0.884**	0.188**	0.192**	-0.004
WHtR	0.770**	0.884**	1	0.168**	0.183**	0.054*
SBP	0.154**	0.188**	0.168**	1	0.726**	0.137**
DBP	0.214**	0.192**	0.183**	0.726**	1	-0.007
Age	-0.120**	-0.004	0.054*	0.137**	-.007	1

** correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Receiver Operating Characteristic (ROC) analyses were used to determine the relative ability of the three-obesity metrics to predict HTN as depicted in Fig. 1 and Table 5. The areas under the curve (AUC) were significantly higher than 0.5 for BMI (0.593, 95% CI: 0.569-0.616), WC (0.610, 95% CI: 0.586-0.633) and WHtR (0.602,0.5 95% CI: 78-0.625). In both gender and all age groups, AUC is significantly higher than 0.5 (P<0.01)

Figure 1: Comparison of the ROC curves of WC, WHR, and BMI in total participants

Table 5. Sex and Age-specific comparisons of the area under ROC curves of BMI, WC, and WHtR

		Area (95% CI) under the curve		
		BMI	WC (CM)	WHtR
All		0.593(0.569-0.616)*	0.610 (0.586-0.633)*	0.602 (0.578-0.625)*
Sex	Male	0.620 (0.585-0.654)*	0.620 (0.586-0.655)*	0.629 (0.595-0.664)*
	Female	0.581 (0.549-0.614)*	0.598 (0.566-0.630)*	0.590 (0.558-0.623)*
Age	40-54	0.600 (0.570-0.631)*	0.606 (0.563-0.625)*	0.594 (0.563-0.625)*
	55-69	0.610 (0.572-0.648)*	0.620 (0.583-0.658)*	0.609 (0.572-0.647)*

* Correlation is significant at the 0.01 level (2-tailed).

Discussion

This descriptive study is an outcome of an opportunistic Risk Factor Screening (RFS) for NCDs, obesity, and HTN at the Health Promotion Unit of a tertiary Eye and ENT hospital in Bhaktapur, Nepal.

The overall prevalence of obesity using BMI in this study was 16.09%, which is higher than obesity prevalence reported in the 2019 NCD Risk Factors STEPS survey Nepal, where only 5.42% of the same age-group were reported be obese [29]. This might be due to the study setting's difference as this study was done in semi-urban area of Kathmandu valley, whereas STEP survey covered both urban and rural areas. Additionally, using BMI, we found that more than two in ten (21.40%) women and nearly one in ten (9.60%) men coming to the hospital were obese, which is nearly double the previously reported values in the Nepal DHS survey of 2016, for both genders (women: 9.5% and men: 5.1%) [24]. Again, these are not comparable because of the different settings in which these studies were done and also different parameters used.

Using International Diabetes Federation recommended cutoff points for south Asians [50] (male 90 cm and female 80 cm) for WC, two-thirds (66.76%) of participants were found to be obese as opposed to only 16.09% measured with BMI. More than three-quarters (77.46%) of women and over half (53.73%) of men were obese in our study.

The overall prevalence of abdominal obesity by WHtR was 32.76%, with higher prevalence among women (40.1%) than men (23.8%). This indicates that obesity measured by WHtR missed a significant proportion of the most important CVD risk factor. Also, WC was able to detect more obesity cases than either BMI or WHtR proving itself superior to the other two metrics.

The observed higher prevalence of body fat in women than men, using all three obesity metrics in our study, is supported by other studies [17, 25, 28]. The reported increase in abdominal obesity with each pregnancy independent of total body fat [54] may explain higher abdominal obesity among women.

Regardless of the metrics used, this study shows a higher prevalence of obesity among Hospital OPD patients, indicating that screening for obesity in this setting has a higher potential to detect a larger number of people with obesity than in community settings; the latter is however, essential for population-based data.

The higher prevalence of obesity in the present study may be due to study design, a selection bias as people reporting to hospitals may also have some or other conditions which could have obesity at the background of their illness. Examined within the larger context of non-utilization of health services, these people may be the ones with better health-seeking behavior, therefore, not truly representative of the community. However, the fact that hospitals draw visitors from their local community would confirm the presence of a high prevalence of this risk factor in the local community. This would need to be confirmed through multi-centric studies in different regions.

To the best of our knowledge, this is the first hospital OPD based data on obesity prevalence from Nepal.

The prevalence of HTN in our study was 40.67%, and men had a slightly higher prevalence of HTN (42.72%) than women (39.00%). *Our findings are comparable to the 2019 STEPS survey Nepal* and 2016 Nepal DHS, where the prevalence of HTN was 40.91% and 32.6%, respectively [26]. In the present study and the other two nation-wide surveys, the prevalence of HTN increased with increasing age. One in three participants with pre-HTN detected in this study would be an important finding indicating the possible group of patients who could turn into hypertensive in near future if not intervened. A disturbing finding of this study was that 57.6% of hypertensive patients, who presumably had betterhealth-seeking behavior, didn't know that they had raised BP before this study. This should alert hospital leaders to launch health promotion programs to raise awareness about HTN in hospitals and their surrounding community.

Although the prevalence of obesity was higher in the present study than nation-wide survey; however, the prevalence of HTN is almost similar to community-based national surveys. Obesity is an earlier event in the evolution of HTN, which develops over a period of time with progressive deposition of atheromatous materials in the blood vessels of people who, by and large, have increased body fat, although HTN can occur in thin people as well. It would, therefore be reasonable to assume that obesity is a precursor of non-genetic HTN and therefore develops earlier than HTN. In this regard, we propose to follow a cohort of our participants who have obesity but did not have raised BP.

At our hospital, we refer persons found to be overweight or obese to a counselor in the next room who advises them for appropriate life style modifications and if necessary, refers to Exercise Medicine unit and to an in-house General Practitioner for any associated disease conditions.

Obesity and Hypertension

In the present study, using all metrics, a significantly higher prevalence of HTN was found among participants with either overweight or obesity compared to participants with normal weight. Also, WC participants greater than the cutoff value were twice (2.02; 95% CI: 1.66-2.45) likely to be hypertensive than people with normal WC. This is supported by several studies in different countries (Italy, USA, India) [52-55].

In the present study, we found a statistically significant positive correlation between all the anthropometric metrics and both SBP and DBP. The present study findings are in agreement with other studies with different populations which support a strong relationship between different obesity metrics and BP across developed and developing countries. The Olivetti Heart Study also showed a weak, but significant and positive correlation between WC and SBP ($r = 0.191$, $P < 0.001$), and DBP ($r = 0.166$, $P < 0.001$) as well [56].

An important finding of the present study is that while BMI, WC, and WHtR were all predictors of HTN, WC was the best predictor overall and BMI the least, WHtR being better predictor for males. However, WC was better for females, both genders combined, and the age-group in the present study. Other studies have also shown that both WC or WHtR is a better predictor for HTN than BMI. A Brazilian cohort study also showed that WC and WHtR were better predictors of HTN in adults over 18, with an AUC value of 0.66 and 0.64, respectively, while BMI was 0.62. However, the associations were only significant for women as in our study [55]. The study in India showed AUC values as 0.694, 0.667 and 0.634 for WHtR, WC and BMI respectively [57]. The study done in eastern India also showed AUC values of BMI, WC, and WHtR were 0.654, 0.676, and 0.693, respectively, indicating WC and WHtR as a better predictor for HTN than BMI [58]

The greater value of this study lies in its ability to signal out very high prevalence of obesity and HTN in people coming to a tertiary care hospital, that is being missed on a day to day basis in clinical setting of busy hospitals of LMIcs.

Limitations of the study

Although prospective, this is still a single-center, observational, cross-sectional study design, hence a causal relationship between an increase in weight over the optimal level and raised BP. The study was performed with the limited objective of finding an inexpensive, simple enough measure of obesity which could be conducted by even non-medical personnel.

Conclusions

The present study showed that WC measured with an inexpensive non-tension tape was not inferior to BMI and WHtR as metrics for obesity detection. Obesity thus detected, correlated well with HTN; had higher predicting ability for HTN than two other metrics (WHtR and BMI). Because of its low cost, simplicity of measurement, and its better ability to predict HTN, it may become a more frequently used tool in health facilities.

However, validation through larger studies in different settings (multicenter studies) is required for further confirmation before becoming a universal tool for routine and research use at the national level. Regardless of the anthropometric metrics to measure obesity, the hospital setting is an opportune venue to screen overweight, obesity, and hypertension, which are major risk factors of NCDs. This is not standard practice as yet in many LMICs.

Finally, this study is an outcome of CHEERS' evolving practice model of proactive, person-centered care, followed at this hospital, which is an approach to reorienting the health system by incorporating health promotion activities in contrast to the mainstream health system's current practice of disease-focused, organ-centered, fragmented care.

List Of Abbreviations

AOR: Adjusted Odds Ratio

AUC: Area Under the Curve

BMI: Body Mass Index

BP: Blood Pressure

CHEERS: Hospital for Children Eye ENT and Rehabilitation Services

CI: Confidence Interval

CM: Centimeter

CMA: Community Medicine Assistant

CVDs: Cardio Vascular Diseases

DBP: Diastolic Blood Pressure

DHS: Demographic and Health Survey

ENT: Ear Nose Throat

GDP: Gross Domestic Product

HTN: Hypertension

RP-RFS: Health Promotion and Risk Factor Screening

KG: Kilograms

LMICs: Low- and Middle-Income Countries

NCDs: Non-Communicable Diseases

ROC: Receiver Operating Characteristic

SBP: Systolic Blood Pressure

SD: Standard Deviation

WC: Waist Circumference

WHO: World Health Organization

WHtR: Waist to Height Ratio

Declarations

- **Ethics approval and consent to participate**

Ethical approval for this study was obtained from Nepal Health Research Council (Reference no. 2910, 2019). Informed consent was taken from every participant before the interview and anthropometric measurement. Participation in this study was voluntary.

- **Consent for publication**

Not applicable

- **Availability of data and materials**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

- **Competing interests**

The authors declare that they have no competing interests

- **Funding**

No funding received for this study

- **Authors' contributions**

RS and MPU designed the study.

RS, BK, JRB were involved in proposal writing.

RS and BK involve in data analysis.

RS, BK, SKU were involved in drafting the manuscript.

RS, BK, MPU, JRB, SKU and MK are involved in critical analysis and review of manuscript.

All authors have read the manuscript carefully and approved its submission.

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Figures

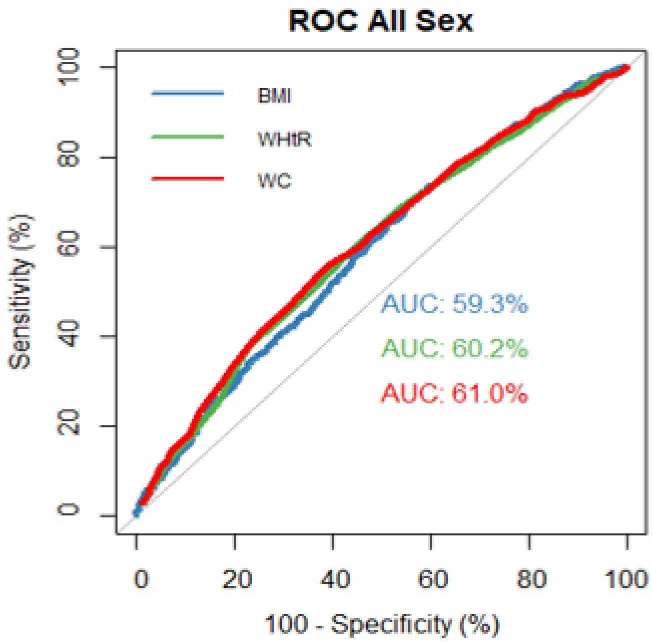

Figure 1

Comparison of the ROC curves of WC, WHR, and BMI in total participants