BMI, waist to height ratio and waist circumference as a screening tool for hypertension in hospital out patients: a cross-sectional study

Rajan Shrestha (✉ rajanshrestha011@gmail.com)

BP Eye Foundation

Bijay Khatri

BP Eye Foundation

Madan P. Upadhyay

BP Eye Foundation

Janak R. Bhattarai

BP Eye Foundation

Manish Kayastha

BP Eye Foundation

Sanjib K. Upadhyay

BP Eye Foundation

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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 of developed world, it has now become a problem of low- and middle-income countries like Nepal. In absence of a routine surveillance or a registry system, the actual burden and trend of obesity in Nepal is unknown. Obesity and overweight are recognized risk factors for hypertension and associated with cardiovascular disease. The aim of the study was to find out burden of obesity, using three commonly employed metrics in hospital outpatient setting of a low-income country as predictors of hypertension, and compare 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 who were evaluated in Health Promotion and risk factor screening service. We did 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 Waist-to-Height-Ratio was 32.76% which is two times higher than obesity measured by BMI. High waist circumference was observed among 66.76% participants. Female participants had greater prevalence of high WC (77.46%) than male (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

Waist circumference correlated well with obesity and hypertension. It also had higher predicting ability than WHtR and BMI to predict hypertension. Waist circumference thus proved to be non-inferior to two other commonly used metrics. It proved superior in detecting obesity in female. This simple and inexpensive 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 adults above 17 years were overweight, and

of those, over 650 million were obese [3]. The trends in adult body mass index (BMI) in 200 countries showed that the age-standardized prevalence of obesity increased from 3.2% to 10.8% in men, and from 6.4% to 14.9% in women from 1975 to 2014 [4]. Obesity is known to be strongly associated with hypertension, heart disease and diabetes [5, 6]. Worldwide, 23%, 45% and 13% of Ischemic heart disease, hypertension and diabetes, respectively [7] have been reported to be associated with obesity. Moreover, obesity and hypertension both are a significant cause of premature death worldwide [8, 9]. WHO estimated that 1.13 billion people worldwide have hypertension; among them, two-thirds are living in low and middle-income countries. The rise in burden of NCDs – major killers of world's population- (such as cardiovascular disease, diabetes, cancer, and chronic obstructive pulmonary disease) closely parallels rise in 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 has also been reported to have resulted in higher incidence of obesity [15].

Long believed to be a condition affecting affluent countries, obesity is on the rise even in low- and middle-income countries (LMICs) [16-18]. Although it co-exists with malnutrition, more people die of obesity in LMICs than under-nutrition [19], true also 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 be able to support the future burden of combined onslaught of NCD and emergent infectious diseases and 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 NCD patients at greater risk of death due to inability to access treatment. The estimated cost of obesity and NCDs to the countries has been estimated to be up to 9.3% GDP [23].

Nepal has, for long, suffered from undernutrition among its children [24]. However, overweight and obesity data available for recent years show an increasing trend for obesity [25-28]. This is not entirely surprising given the fact that the country is rapidly undergoing urbanization, change in lifestyle and dietary pattern [25, 29, 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 LMICS children 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 cardiovascular diseases cause 30% of deaths [35]. Prevalence of hypertension tripled in 25 years between 1981 and 2006 and increased to more than double in 10 years (2008 to 2019) [36, 37]. Similar trend was seen in the prevalence of overweight or obesity which increased from 7.20% to 24.30% between 2008 to 2019 [27, 37]. The eastern regional prevalence of hypertension, overweight and obesity in 2011 was 34%, 28%, and 32% respectively [38].

Like many (LMICs), Nepal is battling a triple burden of diseases: communicable, NCDs, and, injuries with cardiovascular diseases (CVDs) being the most common[39]. Research done particularly in the last decade, has shown that the conventional risk factors for cardio-vascular disease are present in a high proportion in the Nepalese population. [40] In 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 waist to height ratio, WC, blood pressure, which help in detecting the cardiovascular diseases are not routinely practiced in LMICs because of heavy patient load and shortage of staff.

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 Hypertension, though the best anthropometric measurement as predictor of Hypertension remains contentious and controversial. BMI, waist circumference, waist to height ratio are commonly used anthropometric screening tools for predicting Hypertension and other cardiovascular diseases [41]. Some studies have suggested that Waist Circumference (WC) and WHtR may be the better predictors for hypertension and CVD risk [42-47], while other studies suggest that BMI and WC as better predictors of Hypertension [48-50]. A meta-analysis suggested that WC is a better predictor for CVD risks such as Hypertension and recommended that it should be used in clinic and research [51].

Most reported studies on obesity, hypertension and their association have been conducted in community settings. There is paucity of hospital data on burden of obesity, hypertension, and an association between them in outpatient hospital settings of LMICs. So, this study was designed to find out burden of obesity and hypertension, and compare the ability of three different currently available anthropometric measurements to predict hypertension in hospital out patients 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 health promotion and risk factor screening (RFS) service of CHEERS during the study period constituted the study population. The sample size calculation was based on the prevalence of hypertension 46.7% (P) [28]. Margin of error considered as 5% (D), 95% confidence level ($Z=1.96$) and 80% response rate. The formulae use for sample size calculation is $N=(Z^2*P(1-P))/(D^2)$. The calculated sample size is multiplied by number of domains to get 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 existing protocol for obtaining anthropometric measurements for height, weight, waist circumference and blood pressure. The weight, height and waist circumference 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 waist circumference (WC) in cm was measured at the midpoint between the lower edge of the rib cage and the iliac crest after full expiration. BMI was calculated as weight (kg) divided by height squared (m^2). The waist-to-height Ratio (WHtR) was calculated as WC in cm divided by height in cm. Besides anthropometric measurements, socio demographic information and history of hypertension (anti-hypertensive medication) was also enquired.

The standard value for WHtR was considered as 'no increased risk' ($WHtR < 0.5$); 'increased risk' ($WHtR \geq 0.5$ to < 0.6) and 'very high-risk' ($WHtR \geq 0.6$). Similarly, for waist circumference, WC=90 cm for male and WC=80 cm for female was considered as 'cutoff value' [52]. The standard weight status categories associated with BMI range of 18.5 - 24.9 kg/m^2 was considered normal, whereas 25.0 to 29.9 kg/m^2 and 30 kg/m^2 was considered to be overweight and obese respectively [53].

Blood pressure of the participants was measured by aneroid sphygmomanometer with adult cuff size. Participants were asked to sit quietly for 15 mins, leg uncrossed in comfortable position. Blood pressure was measured in left arm placing the cuff at the level of heart, placing the artery mark in the cuff at the level of 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 if systolic blood pressure levels were between 120-139 mmHg and/or diastolic blood pressure levels were between 80-89 mmHg. The participants were also considered hypertensive if they were taking antihypertensive medication, even though their blood pressure at the time of measurement was normal. The participants who did not fit in all of 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, 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 sociodemographic variables, different obesity metrics and behavioral risk factors of hypertension separately; and adjusted odds ratio for hypertensive compared to non-hypertensive group was analyzed by entering age and sex in a model and risk factors with socio-demographic variables in separate different analysis models. Odds ratios 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 Body Mass Index (BMI), Waist to Height Ratio (WHtR) and Waist Circumference (WC) on ability to predict hypertension with 95% confidence interval (CI) were calculated. The confidence interval 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 health promotion and risk factor screening (HP-RFS) service in Hospital for Children Eye ENT and Rehabilitation Services, during June to December 2019. The mean age (SD) 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/m² and 26.72 (4.44) kg/m² for male and female participants respectively (p<0.001). The mean BMI was observed to gradually decrease with advancing age in both male and female participants. The mean waist to height ratio was 0.56 (0.06) and 0.58 (0.08) for male and female (p<0.001). Similarly, Mean Waist circumference was 90.96 (10.32) cm and 88.24 (10.94) cm for male and female respectively (p<0.001).

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

Prevalence of Obesity and overweight

The prevalence of obesity ($\text{BMI} \geq 30 \text{ kg/m}^2$) and overweight ($\text{BMI}: 25.0 \text{ to } 29.9 \text{ kg/m}^2$) was 16.09% and 42.20% respectively. Female participants had higher prevalence of obesity (21.4%) than male (9.6%) ($p\text{-value} < 0.001$). The observed prevalence of overweight among male and female 42.8% and 41.7% respectively, using BMI, is statistically not significant ($p\text{-value} = 0.6121$). Younger age groups have significantly higher prevalence ($p\text{-value} < 0.001$) of overweight and obesity in both genders. Table 2 summarizes obesity and overweight according to gender and age groups. Odds ratio for being obese comparing female to male 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 Waist-to-Height-Ratio was 32.76% which is higher than obesity measured by BMI. Female participants have higher prevalence (40.1%) than male participants (23.8%) and the difference is statistically significant ($p\text{-value} < 0.001$). Age group 40 - 54 had 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 waist circumference was observed among 66.76% participants, female participants have much higher prevalence (77.46%) than male (53.73%) ($p < 0.001$). Thus, WC detected highest prevalence of obesity compared to other two metrics, the prevalence is not significantly different in between age groups.

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

Characteristic	n	Body Mass Index (BMI)			Waist to Height Ratio (WHtR)			Waist Circumference# (CM)	
		≥ 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	$\geq$ 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 1,048	9.60	42.80	47.50	23.80	60.00	16.20	53.73	46.27
age									
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 1,238	21.40	41.70	36.90	40.10	47.60	12.30	77.46	22.54
age									
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 waist circumference for male is 90 cm and for female is 80 cm

Prevalence of Hypertension

Overall prevalence of hypertension and pre hypertension was 40.67% and 36.77% respectively. Male participants had slightly higher prevalence of hypertension (42.72%) than female participants (39.00%). Prevalence, of hypertension for both genders was found to increase as the age group increased. Prevalence of Pre- hypertension was found to be 38.50% and 33.85% among male and female participants. A staggering 81.50% of male and 74.11% of female participants had either established hypertension or pre hypertension (hypertension suspects) A concerning finding was that among 916 participants with hypertension, 57.4% didn't know they had raised blood pressure before this study.

Age adjusted odds ratio for being hypertensive for female compared to male was 0.85 (95% CI:0.72-1.02) and sex adjusted odds ratio for being hypertensive was 1.61 (95% CI: 1.35-1.91) for age group 55-69 compared to age group 40-54.

Table 3: Hypertension, sociodemographic variables and risk factors

		Pre HTN	HTN	Unadjusted Odds Ratio for	Adjusted Odds ratio* for
		n (%)	n (%)	HTN (95% CI)	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 (0.88-1.01)	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 waist circumference for male is 90 cm and for female is 80 cm

* adjusted odds ratio of age and sex were adjusted for sociodemographic variables (age, sex).

Obesity and Hypertension

Prevalence of hypertension among the participants with $BMI \geq 25 \text{ kg/m}^2$, $WHtR \geq 0.5$ and $WC \geq$ cutoff value was 45.97%, 42.52% and 45.28% respectively. Not surprisingly, higher prevalence of hypertension was found among participants with either overweight or obesity compared to participants with normal weight (P-value <0.001). Age and sex adjusted Odds ratio for being hypertensive among high BMI, Waist to Height Ratio and Waist circumference than normal; were 1.74 (95% CI: 1.43-2.03), 1.87 (95% CI:1.43-2.45) and 1.81 (95% CI:1.50-2.17) respectively indicating waist to height ratio and waist circumference's ability to better predict hypertension than BMI

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 Waist circumference and BMI. Waist circumference had highest positive correlation ($r=0.188$, $p<0.01$) with systolic blood pressure than other two metrics. However, BMI had highest positive correlation ($r=0.214$, $p<0.01$) with hypertension than other metrics. The relationship between all three anthropometric metrics and systolic blood pressure was found higher than with diastolic blood pressure.

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

	BMI	WC (CM)	WHtR	SBP	DBP	Age
BMI	1	0.682**	0.770**	0.154**	0.214**	-0.120**
WC (CM)	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**	-0.007	1

Abbreviations: BMI: Body Mass Index; CM: Centimeters; WC: Waist Circumference; WHtR: Waist to Height Ratio.

** 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 (0.570, 95% CI: 0.548-0.592), WC (0.585, 95% CI: 0.563-0.607) and WHtR (0.586, 95% CI:0.564-0.608). In both gender and all age groups, area under the curve 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 Receiver Operating Characteristic (ROC) curves of Body Mass Index (BMI), Waist Circumference (WC) and Waist to Height Ratio (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)*

Abbreviations: BMI: Body Mass Index; CM: Centimeters; WC: Waist Circumference; WHtR: Waist to Height Ratio.

* p<0.01

Discussion

This descriptive study is an outcome of an opportunistic Risk Factor Screening (RFS) for Non communicable diseases, obesity and hypertension at the Health Promotion Unit of a tertiary level Eye and ENT hospital in Bhaktapur, Nepal. The overall prevalence of obesity using BMI in this study was found to be 16.09% which is higher than obesity prevalence reported in the 2019 STEPS survey Nepal, where only 5.42% of same age-group were reported to be obese [37]. This might be due to difference in study area, 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 (21.74%) women and nearly one in ten (10.88%) men coming to hospital were obese, which is nearly double than previously reported values in the Nepal DHS survey of 2016, for both genders (women: 9.5% and men: 5.1%) [24]. However, these are not comparable because of different settings in which these studies were done and also different parameters used. Using International Diabetes Federation cut-off points for south Asians [54], (male 90 cm and for female is 80 cm), for waist circumference, two-thirds (66.76%) of participants were found to be obese as opposed to only 16.1% 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 CV risk factor. Also, WC was able to detect more cases of obesity than either BMI or WHtR thus WC is superior to the other two metrics.

The observed higher prevalence of body fat in women than men, using all three metrics of obesity 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 possibly explain higher abdominal obesity among women. Regardless of the metrics used, this study shows higher prevalence of obesity among Hospital OPD patients, indicating that screening for obesity in this setting has higher potential to detect large number of people with obesity than in community settings. 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 presence of 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 in Nepal.

The prevalence of HTN in our study was 40.67% and men had slightly higher prevalence of HTN (42.72%) than women (39.00%). *Our findings are comparable to 2019 STEPS survey Nepal*, and 2016 Nepal DHS where prevalence of HTN was 40.91% and 32.6% respectively [26]. In the present study as well as the

other two nation-wide surveys, the prevalence of HTN increased with increasing age. One in three participants with **pre hypertension** 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. An important finding of this study, was that 57.6% hypertensive patients, who presumably had better, health seeking behavior, didn't know that they had raised blood pressure before this study, alerts hospital leaders to launch health promotion programs to raise awareness about hypertension in hospitals.

Although the prevalence of obesity was higher in the present study compared to nation-wide survey; however, the prevalence of hypertension is almost similar to community based national surveys. Obesity is an earlier event in the evolution of hypertension, 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 hypertension can occur in these people as well. It would therefore be reasonable to assume that obesity is a precursor of non-genetic hypertension and therefore develops earlier than hypertension. In this regard we propose to follow a cohort of our participants who have obesity but did not have raised blood pressure.

At our hospital, we refer persons found to be OW/Ob 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 if associated disease conditions are seen.

Obesity and Hypertension

In the present study, using all metrics, significantly higher prevalence of hypertension was found among participants with either overweight or obesity compared to participants with normal weight. In the present study, the participants with WC 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) [55-58].

In the present study, we found 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 blood pressure across developed and developing countries. The Olivetti Heart Study also showed a weak, but significant and positive correlation between WC and SBP ($r = 0.191$, $P < .001$), and DBP ($r = 0.166$, $P < .001$) as well [59].

Another finding of the present study is that while BMI, WC, and WHtR all had comparable ability to predict HTN, with WC being the best predictor overall and BMI the least, WHtR being better predictor for male. However, WC was better for female, both genders combined and the age-group in the present study. Other studies have also shown that both WC or WHtR are 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 AUC value of 0.66 and 0.64 respectively, while that for BMI was 0.62. However, the associations were only significant for women as in our study [58]. The study in Indian Capital showed AUC values as 0.694, 0.667 and 0.634 for WHtR, WC and BMI respectively [60]. The study 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 better predictor for HTN than BMI [61].

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.

Limitations of the study

Although prospective, this is still a single center, observational, cross-sectional study design, hence we cannot infer causal relationship between increase in weight over optimal level and raised blood pressure. This study also could not include pregnant women and patients who cannot stand. The study was performed with limited objective of finding an inexpensive, simple enough measure of obesity which could be conducted by even non-medical personnel.

Conclusions

1. The present study showed that waist circumference measured with a non-elastic tape was not inferior to BMI and WHtR as a metrics for obesity detection.
2. Obesity thus detected, correlated well with hypertension; had higher predicting ability for hypertension than two other metrics (WHtR and BMI).
3. Because of its low cost, simplicity of measurement, and its better ability to predict hypertension it may become more frequently used tool in health facilities.
4. However, validation through larger studies in different settings (multicenter studies).are required for further confirmation before becoming an universal tool .for routine and research use at national level.
5. Regardless of the anthropometric metrics to measure obesity, the hospital setting is an opportune venue to screen the overweight, obesity and hypertension, which are major risk factors of NCDs. This

is not a standard practice as yet in many LMI countries.

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

List Of Abbreviations

CHEERS:	Hospital for Children Eye ENT and Rehabilitation Services
BMI:	Body Mass Index
WHtR:	Waist to Height Ratio
WC:	Waist Circumference
WHO:	World Health Organization
NCDs:	Non-Communicable Diseases
LMICs:	Low- and Middle-Income Diseases
GDP:	Gross Domestic Product
CVDs:	Cardio Vascular Diseases
ENT:	Ear Nose Throat
CMA:	Community Medicine Auxiliaries
SBP:	Systolic Blood Pressure
DBP:	Diastolic Blood Pressure
ROC:	Receiver Operating Characteristic
SD:	Standard Deviation
BP:	Blood Pressure
DHS:	Demographic and Health Survey
DALYs:	Disability Adjusted Life Years
AUC:	Area Under the Curve

KG: Kilograms

CM: Centimeters

HTN: Hypertension

CI: Confidence Interval Arrange alphabetically starting with AUC and adding BPEF

Declarations

- **Ethics approval and consent to participate**

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

- **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, JRS, 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