

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

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## Research Article

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# Abstract

**Background:** Obesity has become a global epidemic with a rise in noncommunicable diseases. It is now becoming the problem of low- and middle-income countries such as Nepal. Conventional risk factors are present in a high proportion in the Nepalese population. As a routine surveillance or registry system is absent, the actual burden and trend of obesity and hypertension in Nepal are unknown. Hypertension and other cardiovascular diseases can be prevented by detecting risk factors such as obesity and high blood pressure. A simple anthropometric measurement could be used to determine the risk of hypertension. However, the best predictor of hypertension remains contentious and controversial. We aimed to determine the burden of obesity and hypertension and test the ability to determine hypertension through different anthropometric measurements in hospital outpatients in a low-income setting.

**Methods:** This hospital-based cross-sectional descriptive study was conducted from June to December 2019 among 40-69 year outpatients in a tertiary eye and ENT hospital in a semi-urban area of Nepal among a randomly selected sample of 2,256 participants from 6,769 outpatients visited in Health Promotion and risked factor screening service. We performed a correlation analysis to determine the relationship between anthropometric measurements and blood pressure. The area under the receiver operating characteristic (ROC) curve of body mass index (BMI), waist to height ratio (WHtR) and waist circumference (WC) was calculated and compared.

**Results:** The mean (SD) age of the participants was 51.75 (8.47) years. The overall prevalence of obesity and overweight by BMI was 16.09% and 42.20%, respectively. The overall prevalence of abdominal obesity by waist-to-height ratio was 32.76%, which is higher than obesity by BMI. High waist circumference was observed among 66.76% participants, whereas female participants had a very higher prevalence of high waist circumference (77.46%) and male participants (53.73%) ( $p < 0.001$ ). The prevalence of hypertension among the participants with  $BMI \geq 25 \text{ kg/m}^2$ ,  $WHtR \geq 0.5$  and  $WC \geq$  cutoff values was 45.97%, 42.52% and 45.28%, respectively. The overall prevalence of hypertension and prehypertension was 40.67% and 36.77%, respectively. Male participants had a slightly higher prevalence of hypertension (42.72%) than female participants (39.00%). The areas under the curve (AUCs) 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 genders, the area under the curve was significantly higher than 0.5 ( $P < 0.01$ ). In all age groups, the area under the curve was also significantly higher than 0.5.

**Conclusion:** Waist circumference was both correlated as well as had higher predictive capacity amongst WHtR and BMI and may play a major role in the future diagnosis of HTN in Nepali adults. Regardless of the anthropometric metrics used to measure overweight and obesity, the hospital setting is an opportunity centre to screen for overweight, obesity and hypertension, which are major risk factors for NCDs.

## 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]. The world is suffering from an epidemic of overweight and obesity [5]. It is now recognized as a very common progressive, relapsing, chronic disease responsive to appropriate interventions [6]. Obesity is strongly associated with hypertension [7, 8]. Worldwide, this was 23%, 45% and 13% attributable to ischemic heart disease, hypertension and diabetes, respectively [9]. Moreover, obesity and hypertension are both significant causes of premature death worldwide [10, 11]. The 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 the burden of NCDs – major killers of the world's population- (such as cardiovascular disease, diabetes, cancer, and chronic obstructive pulmonary disease) closely parallels the rise in the burden of obesity [12, 13]. Most NCDs have obesity as an important risk factor [14, 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], so that more people die of obesity in LMICs than under-nutrition [19]. If the same trend continues, the health system in LMICs can no longer support the future burden of NCDs [20]. The estimated cost of obesity and NCDs to the countries has been estimated to be up to 9.3% GDP [21].

Nepal has long suffered from undernutrition among its children [22]. However, overweight and obesity data available for recent years show an increasing trend for obesity [23-26]. This is not entirely surprising given that the country is rapidly undergoing urbanization, changes in lifestyle and dietary patterns [23, 27, 28]. Even in Nepal, overweight and obesity kill more people than underweight [29]. Based on the global burden of disease data, the cause of death from NCDs in Nepal reached 66% from 36.1% in 2009 to 2017 [30, 31]. Additionally, it has also been reported that overweight, obesity and NCDs occur more frequently among adults who have been undernourished in childhood [32, 33].

Noncommunicable diseases country profiles 2018 estimated that NCDs account for 66% of all deaths in Nepal, in which cardiovascular diseases cause 30% of deaths.[34]. The prevalence of hypertension in 25 years had tripled (1981 vs 2006) [35]. Recent studies also showed a rapid increase from 9.30 to 24.5 in ten years (2008 to 2019). A similar trend was observed in the prevalence of overweight or obesity, which increased from 7.20% to 24.30%. [25, 36] The regional prevalence of hypertension, overweight and obesity was 34%, 28%, and 32%, respectively [37].

Like many (LMICs), Nepal is battling a triple burden of diseases: communicable, NCDs, and injuries with cardiovascular diseases (CVDs) being the most common. Research work done mainly in the last decade has shown that the common risk factors are present in a high proportion in the Nepalese population. [38] As a routine surveillance or registry system is absent, the actual burden and trend of CVDs in Nepal are unknown. Primary prevention of cardiovascular disease is an utmost priority in recent years, as the risk of cardiovascular disease can be prevented by detecting risk factors such as obesity and high blood pressure. Early detection of individuals at high CVD risk is the cornerstone of primary prevention. Simple screening methods, such as measuring the waist-to-height ratio and blood pressure, help in detecting cardiovascular disease.

A simple anthropometric measurement could be used to determine the risk of hypertension. Several studies show that different anthropometric measurements of obesity can predict CVD risk, such as hypertension,

although the best predictor of hypertension remains contentious and controversial. BMI, waist circumference, and waist to height ratio are anthropometric screening tools for predicting hypertension and other cardiovascular diseases [39]. Some studies suggest that waist circumference (WC) and WHtR may be better predictors for hypertension CVD risk [40-45], and some studies suggest that BMI and WC are predictors of hypertension [46-48]. A meta-analysis suggests that the WC was a better predictor for CVD risks such as hypertension and recommends that it should be used in the clinic and research [49].

Most of the studies on obesity, hypertension and their association were conducted in community settings. There is a paucity of evidence on the burden of obesity, hypertension, their association and the predictability of hypertension by BMI, WHtR and WC is lacking in the Nepalese setting. Therefore, this study aims to determine the burden of obesity and hypertension and to test the ability to determine hypertension through different anthropometric measurements in hospital outpatients in a 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 participant aged 40 to 69 visiting the health promotion and risk factor screening 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) (steps 2013). The margin of error was 5% (D), the 95% confidence level ( $Z=1.96$ ) and the 80% response rate. The formula used for sample size calculation is  $N=(Z^2*P(1-P))/(D^2)$ . The calculated sample size is multiplied by a number of domains to obtain the final sample size. The number of domains was decided by 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, and informed consent was obtained before anthropometric measurements. Pregnant women and people unable to stand properly were excluded from data analysis for this study.

We followed a standardized protocol at the hospital for anthropometric measurements. Community medicine auxiliaries (CMAs) were trained on an 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 caps 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. The BMI was then 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. In addition to anthropometric measurements, socio-demographic information, current smoking and drinking habits and history of hypertension (hypertensive medication) were also asked.

The standard values for WHtR were considered 'no increased risk' (WHtR <0.5); 'increased risk' (WHtR  $\geq 0.5$  - <0.6) and 'very high-risk' (WHtR  $\geq 0.6$ ) [50]. Similarly, for waist circumference, WC > 94 cm for males and WC > 80 cm for females were considered as 'cutoff values' [51]. The standard weight status categories

associated with a BMI range of 18.5 - 24.9 were considered normal, whereas 25.0 to 29.9 and 30 were considered to be overweight and obese, respectively [52].

The participants were classified as hypertensive if their systolic blood pressure (SBP) was  $\geq 140$  mmHg and/or diastolic blood pressure (DBP)  $\geq 90$  mmHg and prehypertensive 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 measurement was normal. The participants who did not fit in all of the above categories were considered normotensive.

Data analysis was performed using R, version 4.0.0. Continuous variables are shown as the mean, standard deviation [3], and categorical variables as frequency and percentage. Independent sample t-tests were performed to compare the mean values of the continuous variables between different groups. We used logistic regression analysis to find the effect of socio-demographic and different obesity metrics and behavioural risk factors on hypertension separately and in combination. The adjusted odds ratio for hypertensive compared to the nonhypertensive group was analyzed by entering age and sex in a model and risk factors with sociodemographic variables in separate different analysis models. Odds ratios were also reported in 95% confidence intervals. We calculated correlation analysis and calculated Spearman's product-moment correlation coefficient. The area under the receiver operating characteristic (ROC) curve of body mass index (BMI), waist to height ratio (WHtR) and waist circumference (WC) for predicting hypertension and 95% confidence interval (CI) were calculated. The confidence interval, which did not include 0.5, was considered to indicate significant results. A p-value  $<0.05$  in all tests was considered significant.

## Results

This study included 2,256 randomly selected participants from 6,769 people aged 40-69 years who visited health promotion and risk factor screening services in the Hospital for Children Eye ENT and Rehabilitation Services from June to December 2019. The mean age (SD) of the participants was 51.75 (8.47) years.

### *Prevalence of Obesity and overweight*

The mean (SD) BMI was 25.29 (3.81)  $\text{kg}/\text{m}^2$  and 26.72 (4.44)  $\text{kg}/\text{m}^2$  among male and female participants, respectively. The mean BMI gradually decreased from younger age to older age groups in both males and females. The overall prevalence of obesity ( $\text{BMI} \geq 30 \text{ kg}/\text{m}^2$ ) and overweight was 16.09% and 42.20%, respectively. However, female participants had a higher prevalence of obesity (21.4%) than male participants (9.6%) (p-value $<0.001$ ). The burden of obesity was higher among the younger age group in both genders.

The overall prevalence of overweight among males and females was 42.8% and 41.7%, respectively, which was not statistically significant (p-value = 0.6121). Younger age groups had a significantly higher prevalence (p-value  $<0.001$ ) of overweight in both genders. Table 2 summarizes obesity and overweight according to gender and age groups. The odds ratio for being obese compared with 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 overall prevalence of abdominal obesity by waist-to-height ratio was 32.76%, which is higher than obesity by BMI. Female participants had a higher prevalence (40.1%) than male participants (23.8%), and the difference was statistically significant (p-value < 0.001). The 40-54 age group had a significantly higher prevalence of abdominal obesity among female participants (37.59% vs 44.52%, p=0.0195) but not among male participants (23.96% vs 23.66%, p=0.974).

**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	
<b>SBP</b>	118.46	14.96	122.77	16.49	<0.001	121.47	15.50	118.90	15.74	<0.001
<b>DBP</b>	79.21	10.74	79.39	10.25	0.69	79.98	10.67	78.69	10.43	<0.01
<b>Weight (KG)</b>	65.55	10.81	61.58	11.41	<0.001	67.41	11.15	61.32	10.48	<0.001
<b>Height (CM)</b>	157.60	8.84	155.47	9.15	<0.001	163.19	7.23	151.54	6.62	<0.001
<b>WC (CM)</b>	89.51	10.38	89.40	11.36	0.83	90.96	10.32	88.24	10.94	<0.001
<b>WHtR</b>	0.57	0.07	0.58	0.08	0.02	0.56	0.06	0.58	0.08	<0.001
<b>BMI</b>	26.41	4.08	25.50	4.41	<0.001	25.29	3.81	26.72	4.44	<0.001

High waist circumference was observed among 66.76% participants, whereas female participants had a very higher prevalence of high waist circumference (77.46%) and male participants (53.73%) (p<0.001). There was no significant difference between the age groups in both genders (in males; p=0.125, in females; p=0.807).

**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 <sup>2</sup>	25.0 - 29.9 kg/m <sup>2</sup>	< 25.0 kg/m <sup>2</sup>	> 0.60	0.50 - 0.59	< 0.50	≥ cut off	< cut off	
<b>All</b>	2,256	16.09	42.20	41.71	32.76	53.19	14.05	66.76	77.46	
<b>Male</b>	All age	1,048	9.6	42.8	47.5	23.8	60.0	16.2	53.73	46.27
	<b>40-54</b>	634	10.88	47.48	41.64	23.65	60.25	16.09	55.68	44.32
	<b>55-69</b>	384	7.55	35.16	57.29	23.96	59.63	16.41	50.52	49.48
<b>Female</b>	All age	1,238	21.4	41.7	36.9	40.1	47.6	12.3	77.46	22.54
	<b>40-54</b>	782	21.74	44.37	33.89	37.59	50.00	12.40	77.75	22.25
	<b>55-69</b>	456	20.83	37.06	42.10	44.52	43.42	12.06	76.97	23.06

# cut off value of waist circumference for males is 90 cm and for females is 80 cm

### ***Prevalence of Hypertension***

The overall prevalence of hypertension and prehypertension was 40.67% and 36.77%, respectively. Male participants had a slightly higher prevalence of hypertension (42.72%)

**Table 3: Hypertension, sociodemographic variables and risk factors**

		Pre HTN n (%)	HTN n (%)	Unadjusted Odds Ratio for HTN (95% CI)	Adjusted Odds ratio* for HTN (95% CI)
<b>All</b>		828 (36.77)	916 (40.67)		
<b>Sex</b>	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)
<b>Age group</b>	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)
<b>BMI</b>	< 25 kg/m <sup>2</sup>	337 (35.93)	312 (33.26)	1	1
	≥ 25 kg/m <sup>2</sup>	491 (37.37)	604 (45.97)	1.74 (1.43-2.03)	1.89 (1.58-2.26)
<b>WHtR</b>	< 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)
<b>WC# (CM)</b>	< 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)
<b>Current Alcohol Drinker</b>	no	785 (36.96)	853 (40.16)	1	1
	yes	42 (33.33)	62 (49.21)	1.44 (1.01-2.07)	1.43(0.84-1.73)
<b>Current Smoker</b>	no	785 (37.17)	851 (40.29)	1	1
	yes	42 (30.43)	64 (46.38)	1.28 (0.91-1.81)	1.21 (0.85-1.73)

# cut off value of waist circumference for males is 90 cm and for females is 80 cm

\* Adjusted odds ratios of age and sex were adjusted for sociodemographic variables (age, sex). Odds ratios for risk factor variables were adjusted for age and sex variables.

than female participants (39.00%). Hypertension was found in higher prevalence among the age groups increased in both genders. Prehypertension was found in 38.50% and 33.85% of male and female



participants, respectively. In comparison, 81.50% male and 74.11% female participants had either hypertension or prehypertension. Among 916 participants with hypertension, 57.4% did not know they had raised blood pressure before this study.

The age-adjusted odds ratio for being hypertensive for females compared to males was 0.85 (95% CI: 0.72-1.02), and the sex-adjusted odds ratio for being hypertensive was 1.61 (95% CI: 1.35-1.91) for the 55-69 age group compared to the 40-54 age group. Approximately half of the participants (49.21%) who were current alcohol drinkers had hypertension, and 33.33% had prehypertension. Similarly, 46.38% and 30.43% of current smokers had hypertension and prehypertension, respectively.

### ***Obesity and Hypertension***

The prevalence of hypertension among the participants with  $BMI \geq 25 \text{ kg/m}^2$ ,  $WHtR \geq 0.5$  and  $WC \geq$  cutoff values was 45.97%, 42.52% and 45.28%, respectively. A significantly 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 ratios for hypertension among high BMI, waist to height ratio and waist circumference 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.

Table 4 shows the correlations between BMI, WC, WHtR, BP and age, including the level of significance. A strong positive correlation (P<0.01) was found between waist circumference and waist to height ratio with BMI. A significant (p<0.01) positive but weak correlation between both systolic and diastolic blood pressure and BMI was found. The relationship of BMI with diastolic BP was stronger than systolic BP. A similar relationship was also found in WC and WHtR. Age had a weak negative correlation with both BMI (-0.120) significant at the 0.01 level and WC (-0.004) significant at the 0.05 level but had a weak positive correlation with WHtR (0.054) (P-value <0.05).

**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 (AUCs) 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 genders, the area under the curve was significantly higher than 0.5 ( $P < 0.01$ ). In all age groups, the area under the curve was also significantly higher than 0.5.

**Table 5. Sex- and age-specific comparisons of the area under the 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
<b>All</b>		0.593(0.569-0.616)*	0.610 (0.586-0.633)*	0.602 (0.578-0.625)*
<b>Sex</b>	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)*
<b>Age</b>	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 study is a result of a health promotion initiative and an opportunistic screening of obesity and hypertension in a tertiary level Eye and ENT hospital in Bhaktapur, Nepal.

In terms of BMI, the overall prevalence of obesity was 16.09% in our study, which is higher than the *2019 STEPS survey Nepal, where 10.4% of the same age group were obese*. More than two in ten (21.4%) women were obese, whereas nearly one in ten (9.6%) men were obese in our study, which is nearly twice for both genders (women: 9.5% and men: 5.1%) compared to the Nepal DHS survey of 2016 [24]. In addition, overweight and obesity decreased with increasing age group in our study for both genders. In terms of waist circumference, two-thirds (66.76%) people had their waist circumference above the cutoff point. It is more than twice for the same age group compared to the 2019 STEPS survey. More than three-fourths (77.46%) and more than half (53.73%) of women and men, respectively, had waist circumference more than recommended optimally in our study. The overall prevalence of abdominal obesity by WtHR was 32.76%, and women had a higher prevalence (40.1%) than men (23.8%) in our study. We did not find any published materials regarding the WtHR study in the Nepali population to compare. However, a study in neighboring

India among 20- to 60-year-olds in the capital city showed a high WHtR (>0.50) in 69.9% of the population (69.1% males and 71% females) [53].

All three metrics of obesity in our study showed that women were comparatively obese in a higher proportion than men, which is also supported by other national and international literature [17, 23, 26]. It is known that abdominal obesity may increase substantially with each pregnancy independent of total body fat [54], which may explain the higher overweight and obesity among women. The higher prevalence of obesity in the present study may be due to study design, a selection bias as people reporting to hospitals may have some or other conditions that can have obesity in the background of their illness. To the best of our knowledge, there is no OPD-based prevalence of obesity data available in Nepal for comparison.

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 those of the 2019 STEPS survey Nepal* and 2016 Nepal DHS, where the prevalence of HTN was 40.91% and 32.6%, respectively [24]. In the present study and these two nationwide surveys, the prevalence of HTN increased with increasing age group. In this study, 57.6% of hypertensive patients did not know they had raised blood pressure levels before this study, whereas it was 72.5% of hypertensive adults of the same age group in the 2019 STEPS survey of Nepal.

The prevalence of obesity was higher in the present study than in the nationwide survey, but the prevalence of hypertension was similar. This study shows that screening for obesity and hypertension at the health care facility level can catch similar numbers of obese, hypertensive people than lengthy and costly community surveys. This can be a real game changer in the opportunistic screening of obesity and hypertension in low- and middle-income countries (LMICs). Opportunistic screening can lead to early diagnosis of and, if followed up by intervention for obesity and hypertension, will prevent many NCDs, which in turn can reduce DALYs, improve the quality of life of people and reduce the economic burden of those countries arising from needing to tackle NCDs.

### ***Obesity and Hypertension***

The growing prevalence of overweight and obesity has been increasingly recognized and well established as one of the most critical risk factors for the development of hypertension. In the present study, a significantly higher prevalence of hypertension was found among participants with either overweight or obesity compared to participants with a healthy weight for all metrics. Most studies have shown that an increase in BMI also raises blood pressure levels [55-58]. The 2016 Nepal DHS also showed that rates of hypertension among women and men increase with increasing BMI. In the present study, the participants with WC greater than the cutoff were nearly twice (1.81) likely to be hypertensive. A study in Italy in 2001 also showed similar results, where men were three times more likely, and women were twice likely to have hypertension with WC higher than the cutoff point [59]. A study in the southeastern US also showed that hypertension increased with increasing WC [60], whereas a study among adults aged 18 and above in Srinagar, India showed that 69.0% of people with abnormal WC were hypertensive [61]. In the present study, the participants with WHtR  $\geq 0.5$  had odds of 1.81 being hypertensive. A longitudinal study between 2005-2008 among Korean adults aged 39-72 years showed that the participants with the highest quartile of the WHtR

(WHtR $\geq$ 0.54) were 4.51 times more likely to have hypertension [62]. A cohort study in Brazil among adults aged 18 years and above also showed that participants with beyond optimal BMI, WC and WHtR were more hypertensive than within normal metrics, and 48.0%, 54.0%, and 73.0% of participants who were overweight at baseline according to BMI, WC and WHtR, respectively, developed HTN over time [63]. The present study corroborates the fact that overweight and obesity are significant risk factors for hypertension.

In the present study, we found a statistically significant positive correlation between all anthropometric metrics and both SBP and DBP. The present study findings are in agreement with other studies with different populations that support a strong relationship between different obesity metrics and blood pressure across developed and developing countries. A study among Punjabi adults residing in Delhi aged 18-50 in India showed a significant relationship between BMI and both SBP ( $r=0.30$ ,  $p<0.01$ ) and DBP ( $r=0.35$ ,  $p<0.01$ ) [64]. A similar relationship was observed in a study among students and staff aged 18 and above of a university in Nepal between BMI and SBP ( $r=0.414$ ,  $P<0.01$ ) and DBP ( $r=0.414$ ,  $P<0.01$ ), as well as with WC and SBP ( $r=0.445$ ,  $P<0.01$ ) DBP ( $r=0.454$ ,  $P<0.01$ ) [65]. The Olivetti Heart Study also showed a significant and positive correlation between WC and SBP ( $r = 0.191$ ,  $P < .001$ ) and DBP ( $r = 0.166$ ,  $P < .001$ ) [66]. In a study of the 20–80-year-old urban population of eastern India, WHtR had relatively higher correlation coefficients for HTN. The correlation coefficients for SBP and DBP amongst men were 0.362 and 0.330, respectively, whereas for women, the correlation coefficients were 0.395 and 0.365 for SBP and DBP, respectively [67].

Another finding of the present study is that BMI, WC, and WHtR had significant and comparable ability to predict HTN, but BMI had the least. The WHtR was a better predictor for males, but overall WC was better for females, both genders combined and the age group in the present study. Other literature also shows that either WC or WHtR is a better predictor for HTN than BMI. The ARIRANG study among Korean adults showed that the AUC in ROC curves for WHtR and BMI were 0.662 ( $p=0.02$ ) and 0.623 ( $p=0.38$ ), respectively [62]. The Brazilian cohort study also showed that WC and WHtR were better predictors of HTN, with AUC values for adults above 18 years of age of 0.66 and 0.64, while that of BMI was 0.62, but the associations were only significant for women. [63]. However, a study in the Filipino-American Cardiovascular study among women aged 40-65 years showed that BMI was a better predictor than WHtR and WC, with AUC values of 0.660, 0.650 and 0.629, respectively [68]. The study in Indian capital showed AUC values of 0.694, 0.667 and 0.634 for WHtR, WC and BMI, respectively [53]. The study in eastern India also showed that the AUC values of BMI, WC and WHtR were 0.654, 0.676 and 0.693, respectively, indicating WHtR as a better predictor for HTN than other metrics [67].

### **Limitations of the study**

Although prospective, this is still an observational, cross-sectional study design; hence, we cannot infer a causal relationship between an increase in weight over an optimal level and raised blood pressure. The higher value of this study lies in its ability to signal out that a very high proportion of people coming to the hospital have overweight/obesity and hypertension that is being missed on a day-to-day basis in a clinical setting.

## Conclusions

The present study showed that waist circumference, which is easy to measure, was both correlated and had higher predictive capacity among WHtR and BMI and may play a major role in the future diagnosis of HTN in Nepali adults. Regardless of the anthropometric metrics used to measure overweight and obesity, the hospital setting is an opportunity centre to screen for overweight, obesity and hypertension, which are major risk factors for NCDs.

## Declarations

- Ethics approval and consent to participate

Ethical approval for this study was obtained from the Nepal Health Research Council (Reference no. 2910). Informed consent was obtained 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, and JRB were involved in proposal writing. RS and BK were involved in data analysis. RS, BK, and SKU were involved in drafting the manuscript. RS, BK, MPU, JRS, SKU and MK are involved in critical analysis and review of the manuscript. All authors have read the manuscript carefully and approved its submission.

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## 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:	Cardiovascular 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

## References

1. Ng, M., et al., *Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013*. The Lancet, 2014. **384**(9945): p. 766-781.
2. Popkin, B.M., *The world is fat*. Scientific American, 2007. **297**(3): p. 88-95.
3. Di Cesare, M., et al., *Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19.2 million participants*. Lancet, 2016. **387**(10026): p. 1377-1396.
4. *Obesity and overweight*. 2018 16 February 2018 [cited 2018 27 December 2018]; Available from: <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>.
5. Popkin, B.M. and C.M. Doak, *The obesity epidemic is a worldwide phenomenon*. Nutrition reviews, 1998. **56**(4): p. 106-114.
6. Bray, G.A., et al., *obesity: a chronic relapsing progressive disease process. A position statement of the World Obesity Federation*. Obes Rev, 2017. **18**(7): p. 715-723.
7. Hall, J.E., et al., *Obesity-associated hypertension and kidney disease*. Current opinion in nephrology and hypertension, 2003. **12**(2): p. 195-200.
8. Rahmouni, K., et al., *Obesity-associated hypertension: new insights into mechanisms*. Hypertension, 2005. **45**(1): p. 9-14.
9. World Health Organization, *Global health risks: mortality and burden of disease attributable to selected major risks*. 2009.
10. Collaboration, P.S., *Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies*. The Lancet, 2009. **373**(9669): p. 1083-1096.
11. (WHO), W.H.O. *Hypertension*. 2019 13 September 2019; Available from: <https://www.who.int/news-room/fact-sheets/detail/hypertension>
12. Hannah Rithie and Max Roser. *"Obesity and BMI"*. 2019; Available from: <https://ourworldindata.org/obesity>.
13. Ritchie, M.R.a.H. *Burden of Disease*. 2019; Available from: <https://ourworldindata.org/burden-of-disease>.
14. Organization, W.H. and W.H. Organization, *Burden: mortality, morbidity and risk factors*. Global status report on noncommunicable diseases, 2010. **2011**.
15. Banjare, J.B. and S. Bhalerao, *Obesity associated noncommunicable disease burden*. International Journal of Health & Allied Sciences, 2016. **5**(2): p. 81.
16. Bhurosy, T. and R. Jeewon, *Overweight and obesity epidemic in developing countries: a problem with diet, physical activity, or socioeconomic status?* The Scientific World Journal, 2014. **2014**.
17. Ford, N.D., S.A. Patel, and K.V. Narayan, *Obesity in low-and middle-income countries: burden, drivers, and emerging challenges*. Annual review of public health, 2017. **38**: p. 145-164.
18. Popkin, B. and M. Slining, *New dynamics in global obesity facing low-and middle-income countries*. Obesity Reviews, 2013. **14**: p. 11-20.
19. Basnyat, B. and L.C. Rajapaksa, *Cardiovascular and infectious diseases in south asia: the double whammy: innovation, political commitment, and new partnerships are needed*. BMJ: British Medical

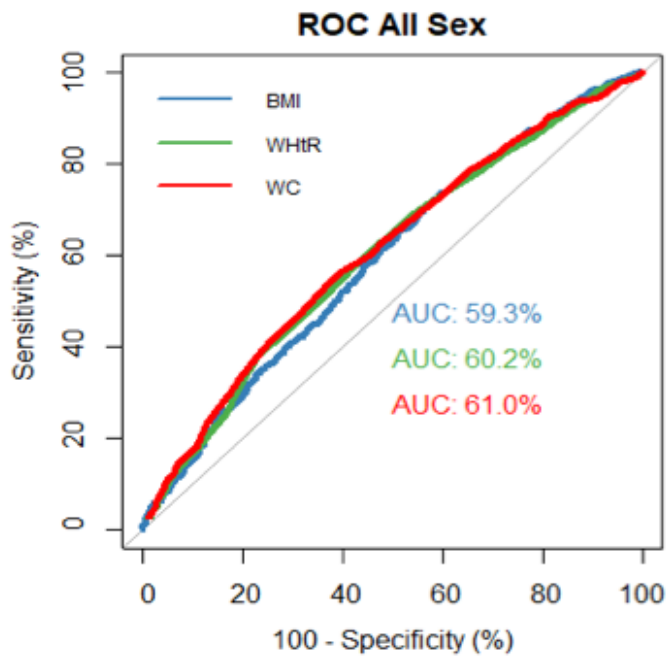
- Journal, 2004. **328**(7443): p. 781.
20. Boutayeb, A. and S. Boutayeb, *The burden of non communicable diseases in developing countries*. Int J Equity Health, 2005. **4**(1): p. 2.
  21. Hugh Waters and Marlon Graf, *America's Obesity Crisis*. 2018.
  22. Joshi, P., *Malnutrition in children: A serious public health issue in Nepal*. Health Prospect, 2013. **11**: p. 61-62.
  23. Vaidya, A., S. Shakya, and A. Krettek, *Obesity prevalence in Nepal: public health challenges in a low-income nation during an alarming worldwide trend*. Int J Environ Res Public Health, 2010. **7**(6): p. 2726-44.
  24. Ministry of Health, *Nepal Demographic and Health Survey*. 2016.
  25. Nepal Health Research Council, *Non Communicable Diseases Risk Factors Survey, 2007/08*. 2008.
  26. Nepal Health Research Council, *Non Communicable Diseases Risk Factors: STEPS Survey Nepal 2013*. 2013.
  27. Vaidya, A., S. Shakya, and A. Krettek, *Obesity prevalence in Nepal: public health challenges in a low-income nation during an alarming worldwide trend*. International journal of environmental research and public health, 2010. **7**(6): p. 2726-2744.
  28. Subedi, Y.P., D. Marais, and D. Newlands, *Where is Nepal in the nutrition transition?* Asia Pacific journal of clinical nutrition, 2015.
  29. Khadaee, G.H. and M. Saeidi, *Increases of Obesity and Overweight in Children: an Alarm for Parents and Policymakers*. International journal of pediatrics, 2016. **4**(4): p. 1591-1601.
  30. Nepal Health Research Council, M.o.H.P., Monitoring Evaluation and Operational Research, *Nepal Burden of Disease 2017: A country Report based on the Global Burden of Disease 2017 Study*. Kathmandu, Nepal. 2019: NHRC, MoHP, and MEOR.
  31. Nepal Health Research Council (NHRC), *Assessment of Burden of Disease in Nepal 2009*. 2018: Kathmandu, Nepal.
  32. Wilson, H.J., et al., *Fat free mass explains the relationship between stunting and energy expenditure in urban Mexican Maya children*. Ann Hum Biol, 2012. **39**(5): p. 432-9.
  33. Victora, C.G., et al., *Maternal and child undernutrition: consequences for adult health and human capital*. Lancet, 2008. **371**(9609): p. 340-57.
  34. Organization, W.H., *Noncommunicable diseases country profiles 2018*. 2018.
  35. Vaidya, A., R.P. Pathak, and M.R. Pandey, *Prevalence of hypertension in Nepalese community triples in 25 years: a repeat cross-sectional study in rural Kathmandu*. Indian heart journal, 2012. **64**(2): p. 128-131.
  36. Dhimal M, B.B., Bhattarai S, Dixit LP, Hyder MKA, Agrawal N, Rani M, Jha AL., *Report of Non Communicable Disease Risk Factors: STEPS Survey Nepal 2019*. 2020, Kathmandu, Nepal: Nepal Health Research Council (NHRC).
  37. Sharma, S.K., et al., *prevalence of hypertension, obesity, diabetes, and metabolic syndrome in Nepal*. International journal of hypertension, 2011. **2011**.



38. Health, M.o. and Population, *Nepal noncommunicable diseases risk factors survey 2007*. 2008, Ministry of Health and Population Kathmandu.
39. Organization, W.H., *Waist circumference and waist-hip ratio: report of a WHO expert consultation, Geneva, 8-11 December 2008*. 2011.
40. Park, S.-H., et al., *Waist circumference and waist-to-height ratio as predictors of cardiovascular disease risk in Korean adults*. *Circulation Journal*, 2009. **73**(9): p. 1643-1650.
41. Zeng, Q., et al., *Optimal cutoff values of BMI, waist circumference and waist: height ratio for defining obesity in Chinese adults*. *British Journal of Nutrition*, 2014. **112**(10): p. 1735-1744.
42. Lee, C.M.Y., et al., *Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis*. *Journal of clinical epidemiology*, 2008. **61**(7): p. 646-653.
43. Caminha, T.C., et al., *Waist-to-height ratio is the best anthropometric predictor of hypertension: a population-based study with women from a state of northeast of Brazil*. *Medicine*, 2017. **96**(2).
44. Li, W.-C., et al., *Waist-to-height ratio, waist circumference, and body mass index as indices of cardiometabolic risk among 36,642 Taiwanese adults*. *European journal of nutrition*, 2013. **52**(1): p. 57-65.
45. Sayeed, M., et al., *Waist-to-height ratio is a better obesity index than body mass index and waist-to-hip ratio for predicting diabetes, hypertension and lipidemia*. *Bangladesh Medical Research Council Bulletin*, 2003. **29**(1): p. 1-10.
46. Li, N., et al., *Is waist-to-height ratio superior to body mass index and waist circumference in predicting the incidence of hypertension?* *Annals of Nutrition and Metabolism*, 2019. **74**(3): p. 215-223.
47. Sakurai, M., et al., *Gender differences in the association between anthropometric indices of obesity and blood pressure in Japanese*. *Hypertension Research*, 2006. **29**(2): p. 75-80.
48. Bennasar-Veny, M., et al., *Body adiposity index and cardiovascular health risk factors in Caucasians: a comparison with the body mass index and others*. *PloS one*, 2013. **8**(5): p. e63999.
49. Van Dijk, S., et al., *Different anthropometric adiposity measures and their association with cardiovascular disease risk factors: a meta-analysis*. *Netherlands Heart Journal*, 2012. **20**(5): p. 208-218.
50. Ashwell, M. and S. Gibson, *Waist-to-height ratio as an indicator of 'early health risk': simpler and more predictive than using a 'matrix' based on BMI and waist circumference*. *BMJ open*, 2016. **6**(3): p. e010159.
51. WHO, *Waist Circumference and Waist-Hip Ratio*. 2008.
52. Center for Disease Control. *About Adult BMI*. 2017 [cited February, 2019; Available from: [https://www.cdc.gov/healthyweight/assessing/bmi/adult\\_bmi/index.html](https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html)].
53. Vikram, N.K., et al., *Waist-to-height ratio compared to standard obesity measures as predictor of cardiometabolic risk factors in Asian Indians in North India*. *Metabolic syndrome and related disorders*, 2016. **14**(10): p. 492-499.
54. Danilack, V.A., E.C. Brousseau, and M.G. Phipps, *The Effect of Gestational Weight Gain on Persistent Increase in Body Mass Index in Adolescents: A Longitudinal Study*. *J Womens Health (Larchmt)*, 2018.

55. Landi, F., et al., *Body Mass Index is Strongly Associated with Hypertension: Results from the Longevity Check-up 7+ Study*. *Nutrients*, 2018. **10**(12).
56. Jiang, B., et al., *Hypertension detection, management, control and associated factors among residents accessing community health services in Beijing*. *Sci Rep*, 2014. **4**: p. 4845.
57. Tesfaye, F., et al., *Association between body mass index and blood pressure across three populations in Africa and Asia*. *Journal of Human Hypertension*, 2007. **21**(1): p. 28-37.
58. Wilson, P.W., et al., *overweight and obesity as determinants of cardiovascular risk: the Framingham experience*. *Arch Intern Med*, 2002. **162**(16): p. 1867-72.
59. Guagnano, M.T., et al., *Large waist circumference and risk of hypertension*. *International Journal of Obesity*, 2001. **25**(9): p. 1360-1364.
60. Levine, D.A., et al., *Moderate waist circumference and hypertension prevalence: the REGARDS Study*. *American journal of hypertension*, 2011. **24**(4): p. 482-488.
61. Rouf, A., et al., *prevalence of hypertension and its association with waist circumference in adult population of Block Hazratbal, Srinagar, India*. *Annals of Medical and Health Sciences Research*, 2018.
62. Choi, J.R., S.B. Koh, and E. Choi, *Waist-to-height ratio index for predicting incidences of hypertension: the ARIRANG study*. *BMC public health*, 2018. **18**(1): p. 767-767.
63. Rezende, A.C., et al., *Is waist-to-height ratio the best predictive indicator of hypertension incidence? A cohort study*. *BMC Public Health*, 2018. **18**(1): p. 281.
64. Dua, S., et al., *Body mass index relates to blood pressure among adults*. *North American journal of medical sciences*, 2014. **6**(2): p. 89-95.
65. Awasthi, J.R., et al., *The best anthropometric index to access the risk of hypertension in the population of Kavre district, Nepal*. *Eur. j. anat*, 2015: p. 269-275.
66. Siani, A., et al., *The Relationship of Waist Circumference to Blood Pressure: The Olivetti Heart Study\**. *American Journal of Hypertension*, 2002. **15**(9): p. 780-786.
67. Prasad, D., et al., *Appropriate anthropometric indices to identify cardiometabolic risk in South Asians*. *WHO South-East Asia Journal of Public Health*, 2013. **2**(3-4): p. 142-148.
68. Battie, C.A., et al., *Comparison of body mass index, waist circumference, and waist to height ratio in the prediction of hypertension and diabetes mellitus: Filipino-American women cardiovascular study*. *Preventive Medicine Reports*, 2016. **4**: p. 608-613.

## Figures



**Figure 1**

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