Research Article

Designing a gender-specific colour-coded waist circumference measuring tape-The Mishra's Metabolic & Cellular Optimisation Risk Evaluation Dual Tape' (M-CORE dual tape) as a public health innovation Tool for nutritional Screening in adults

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Background: India, like many developing nations, experiences a 'Double burden' of malnutrition. Although Body Mass Index (BMI) is the standard method for classifying individuals' nutritional status, its user-friendliness and cardiometabolic risk prediction have come under scrutiny. Therefore, the search for alternative, scientifically tenable, simple, inexpensive, and easy-to-use and interpret screening tools, such as M-CORE dual tape, is underway.

Objectives: 1. To evaluate the association between waist circumference and Body Mass Index (BMI), derive gender specific waist circumference categories corresponding to Indian Council of Medical Research (ICMR) BMI classifications, and determine the diagnostic performance of the defined categories in detecting the nutritional status of studied individuals. 2. To develop a sex-specific colour-coded waist circumference measuring tape (M-CORE dual tape) for rapid nutritional screening.

Methods: A community-based cross-sectional study using a population-proportionate sampling technique was conducted to enroll 528 adults from six villages in the rural field practice area of the Department of Community Medicine, of R.D. Gardi Medical College, Ujjain, Madhya Pradesh, using data collected under the Community Adoption Programme for Postgraduates (CAPP), a unique community-oriented academic initiative of the institution. Under this programme, postgraduate students adopted villages and conducted comprehensive community health surveys, including anthropometric assessment and screening for abdominal obesity. Height, weight, waist circumference, and hip circumference. Body Mass Index (BMI) was calculated and classified according to the Indian Council of Medical Research (ICMR) guidelines. Waist circumference values were stratified into percentiles, and the association between waist circumference percentile categories and BMI categories was evaluated. The relationship was further examined using the Chi-square test, one-way Analysis of Variance (ANOVA), and binary logistic regression. The diagnostic performance of waist circumference and BMI for identifying overweight and obesity was assessed using Receiver Operating Characteristic (ROC) curve analysis, and the findings were used to develop/propose a gender-specific colour-coded waist circumference measuring tape: 'Mishra's M-CORE dual tape' for nutritional screening.

Results: Among 528 participants, 232 (43.9%) were male, and 296 (56.1%) were female. The average ages were 49.59 (± 16.66) for males, 51.58 (± 16.75) for females, and 48.06 (± 16.43) overall. The waist circumference percentile categories for the overall study population, as well as for male and female participants, showed very strong associations with ICMR-based BMI grades. This was determined using the Fisher–Freeman–Halton Test ($p < 0.001$, 0.05, and 0.001) and one-way ANOVA ($p < 0.001$). In the regression analysis, the findings for the overweight and obese categories were significant (odds ratio of 5.83 - 56.00, $p < 0.05$- 0.001). The ROC (Receiver Operating Characteristic) analysis yielded positive results, with AUCs ranging from 0.53 to 0.75 across all nutritional grade categories based on county-specific (India) BMI and the proposed waist circumference categories (grades). The analysis placed particular emphasis on gender-specific waist circumference measurements, which were found to have predictive potential (AUC) near equal and at some places better than their corresponding BMI.

For males, the proposed categories(grades) are < 74 cm: severely thin, 74–77 cm: Mildly thin, 77–83cm: Normal, 83–90 cm: Overweight, 90-100 cm: Obesity grade 1, and> 100 cm: Obesity grade 2. For females, ≤76 cm: Severely thin, 76–79cm: Mildly thin, 79–84cm: Normal, 84–90cm: Overweight, 90- 96 cm: Obesity grade 1, and> 96 cm: Obesity grade 2.

Conclusion: Based on the above observations, a gender-specific colour-coded, simple-to-use waist circumference measuring tape (The Mishra's M-CORE dual tape) is proposed for further testing and recommendation for use in different healthcare settings.

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Introduction

The nutritional imbalance in developing nations, including India, is bimodal[1-3]. Undernutrition and obesity have their own story to narrate. Both have a staggering effect on personal and national health and productivity[4-6].

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Issues of hidden hunger amplify the scenario further. The byproducts of these range from stunted and wasted growth, vitamins and mineral deficiencies, cardio-metabolic burden in the form of obesity, diabetes, and hypertension, to name a few[7-10].

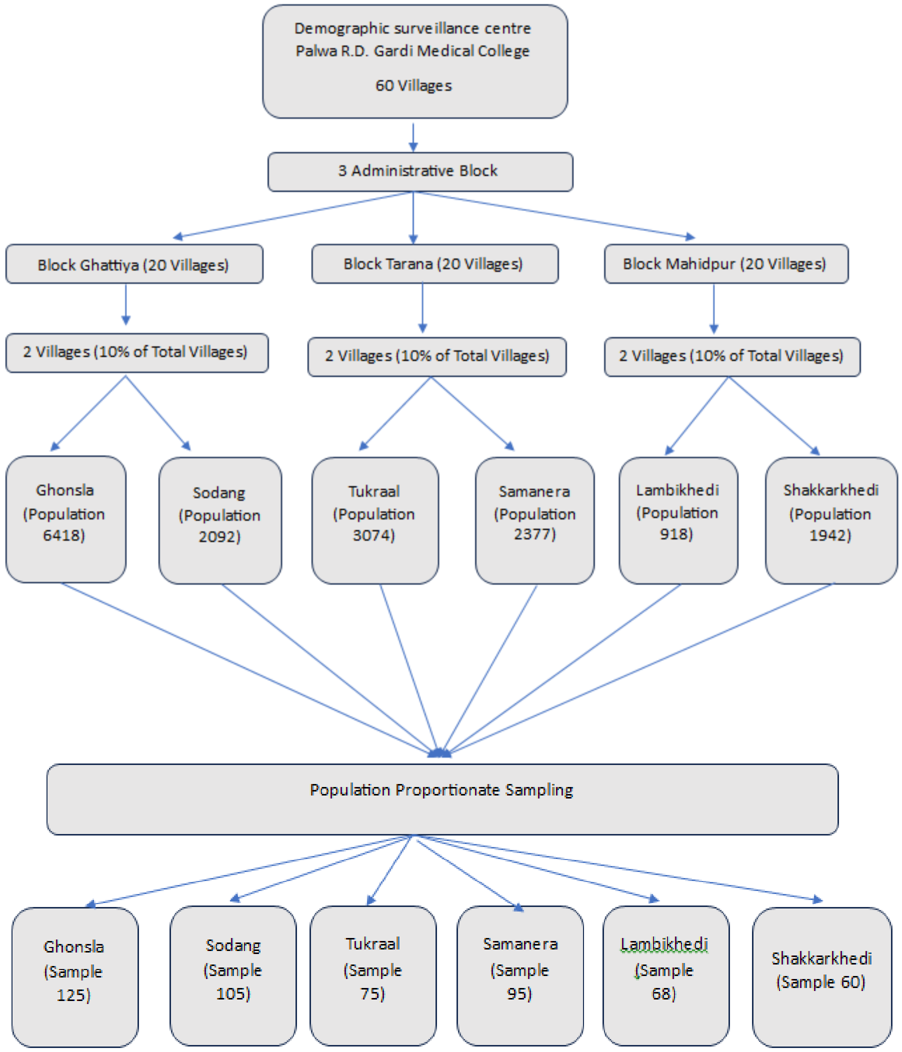
Timely detection of these conditions on a routine basis, especially at ground level, is paramount. The commonly employed measurements in this regard are BMI, Waist circumference, and waist-hip ratio[11-13]. Though body mass index (BMI) is the most commonly used anthropometric indicator, it involves conversion of reading units and cumbersome calculation. It also does not differentiate between fat mass and lean body mass, nor does it provide information regarding body fat distribution[14,15]. Recent recommendations from the India Obesity Commission emphasize that obesity assessment in Asian Indians should not rely solely on Body Mass Index but should incorporate measures of central adiposity, particularly waist circumference, to improve identification of individuals at increased cardiometabolic risk[15]. Asian Indians possess a unique body composition characterized by relatively higher body fat percentage and greater visceral adiposity despite having lower body mass index values than Western populations. Consequently, obesity-related metabolic disorders such as type 2 diabetes mellitus, hypertension, and cardiovascular disease occur at comparatively lower body mass index levels. These ethnic differences have led to the adoption of lower body mass index cut-offs for defining overweight and obesity in Indian adults and highlight the need for anthropometric tools that accurately identify central obesity in this population[16]. Among the available anthropometric indicators, waist circumference (WC) is recognized as a simple, inexpensive, reproducible, and reliable measure of abdominal obesity. Waist circumference correlates closely with visceral adiposity and independently predicts metabolic syndrome, diabetes, cardiovascular disease, and all-cause mortality. An international consensus statement by the International Atherosclerosis Society and the International Chair on Cardiometabolic Risk recommends that waist circumference should be considered a routine “vital sign” in clinical practice because it provides clinically important information beyond Body Mass Index alone[17]. Despite its advantages, waist circumference remains underutilized during community-based screening programmes. Although measurement requires only a non-stretchable measuring tape, interpretation depends on remembering sex-specific cut-off values or consulting reference charts, which may not always be practical during field surveys or outreach activities conducted by frontline healthcare workers. This limits its routine use despite being a rapid and low-cost screening measure[17,18]. Colour-coded anthropometric tools, such as mid-upper arm circumference (MUAC) tapes, have simplified community-based nutritional screening by enabling rapid interpretation without calculations or reference charts. Their simplicity, portability, and minimal training requirements have facilitated widespread use by frontline health workers in resource-limited settings. Similar approaches have also been explored for adult anthropometric screening using simplified circumference-based measures. Applying a colour-coded approach to waist circumference may facilitate rapid identification of overweight and obesity during community-based screening and improve timely counselling and referral[19,20,7,8]. However, to the best of our knowledge, no standardized gender-specific colour-coded waist belt based on anthropometric characteristics of Indian adults has been developed for community-level screening. The recently proposed Indian framework for obesity assessment further highlights the importance of incorporating waist circumference into routine screening, particularly in primary care and community settings. However, practical tools that allow rapid interpretation of waist circumference measurements during field-based screening are currently lacking[15]. Therefore, the present study was undertaken to identify gender-specific waist circumference ranges corresponding to Body Mass Index categories and to develop a gender-specific colour-coded waist belt as an innovative, inexpensive, and field-friendly public health tool for community-based screening of overweight and obesity among Indian adults.

Primary Objective

To design a gender-specific colour-coded waist circumference measuring tape for routine clinics and community-based assessments of nutritional status among adults in the Indian population.

Secondary Objectives

- To identify and validate waist circumference ranges corresponding to both male and female populations with corresponding Body Mass Index categories proposed by ICMR for the Indian population.
- To study the predictive potential of the waist circumference categories (grades) in detecting under- and over-nutritional status.



Materials and Methods

Study Design and Setting

A community-based cross-sectional observational study was conducted using data collected during a community health survey carried out under the Community Adoption Programme for Postgraduates (CAPP)[21] . a unique academic initiative of R.D. Gardi Medical College, Ujjain, Madhya Pradesh, aimed at promoting community-oriented medical education and research. Under this programme, postgraduate students adopt villages in the rural field practice area and conduct comprehensive community health assessments [22]. The present study was conducted in six adopted villages within the field practice area of the Department of Community Medicine, where trained healthcare teams conducted household visits and anthropometric assessments using standardised procedures.

The Demographic surveillance centre Palwa of R.D. Gardi Medical College covers 60 villages, equally distributed across three administrative blocks: Ghattiya (20 villages), Tarana (20 villages), and Mahidpur (20 villages). For the present study, 10% of the villages were selected using block-wise sampling, with two villages selected from each block, resulting in a total of six study villages. Subsequently, participants were allocated to each selected village using population-proportionate sampling based on the population size of each village. Within each village, individuals were then selected for the final study sample using a simple random sampling technique.

The study was undertaken to develop a gender-specific colour-coded waist belt as a simple, low-cost, and field-friendly public health innovation for community-based screening of overweight and obesity among Indian adults. To achieve this, the association between waist circumference and Body Mass Index was examined, gender-specific waist circumference ranges corresponding to different Body Mass Index categories were identified, and the diagnostic performance of waist circumference was evaluated to derive colour zones for the proposed waist belt(tape).

Study Population

The study included adults aged 18 years and above who participated in the community health survey and had complete anthropometric measurements.

Inclusion Criteria

- Adults aged ≥18 years residing in the selected villages.
- Participants with complete anthropometric measurements.

Exclusion Criteria

- Pregnant women.
- Individuals with conditions affecting accurate anthropometric measurements (e.g., ascites, abdominal masses, severe spinal deformity, limb amputation).
- Seriously ill or bedridden individuals.

Data Collection and Anthropometric Measurements

Anthropometric measurements were obtained by trained investigators using standardised techniques. Height was measured using a portable stadiometer to the nearest 0.1 cm, while body weight was measured using a calibrated digital weighing scale to the nearest 0.1 kg. Body Mass Index (BMI) was calculated as weight in kilograms divided by the square of height in metres (kg/m²).

Waist circumference was measured using a non-stretchable measuring tape at the midpoint between the lower margin of the last palpable rib and the iliac crest at the end of normal expiration. Hip circumference was measured at the level of the maximum circumference over the buttocks, and waist-to-hip ratio (WHR) was calculated by dividing waist circumference by hip circumference.

Table 1: Distribution of Study Participants by Village and Gender (N = 528)

Village	*Total population of village*	*Male, n (%)*	*Female, n (%)*	*Total, n (%)*
Ghonsla	6418	55	70	125 (23.7)
Tukral	3074	33	42	75 (14.2)
Samanera	2377	42	53	95 (18.0)
Sodang	2092	46	59	105 (19.9)
Shakkarkhedhi	1942	26	34	60 (11.4)
Lambikhedi	918	30	38	68 (12.9)
Total	16821	232 (43.9%)	296 (56.1%)	528 (100.0%)

Table 2: Baseline Sociodemographic and Anthropometric Characteristics of the Study Participants (N = 528)

Variable	*Value*
Total participants, n	528
Male, n (%)	232 (43.9)
Female, n (%)	296 (56.1)
Mean age (years)	49.59 years
Mean BMI (kg/m²)	22.60 ± 5.01 kg/m²
Mean waist circumference (cm)	86.20 ± 10.14 cm
Mean hip circumference (cm)	92.77 ± 10.28 cm
Mean waist-hip ratio	0.93 ± 0.08

Participants were classified according to the Indian Council of Medical Research (ICMR) BMI classification into (<17 kg/m²) Severely thin,(17.1–18.4kg/m²) Mildly thin, (18.5- 22.9 kg/m²) Normal,(23.0–24.9kg/m²) Overweight,(≥25kg/m²) Obese (10).

To develop the proposed gender-specific colour-coded waist belt, waist circumference values were analysed separately for males and females. The relationship between waist circumference and Body Mass Index categories was examined, and waist circumference ranges corresponding to different Body Mass Index categories were identified. These findings, along with the diagnostic performance of waist circumference, were used to derive gender-specific colour zones for the proposed colour-coded waist measurement tape(belt).

Statistical Analysis

Data were entered into Microsoft Excel and analysed using the Statistical Package for the Social Sciences (SPSS) version 23.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were expressed as frequencies, percentages, means, and standard deviations. The association between waist circumference categories

Table 3: Percentile Distribution of Waist Circumference Among all Participants, male and female (n = 528)

Percentile	*Overall*	*Male*	*Female*
5th	72	72	72
10th	75	75	75
25th	80	80	80
50th	85	86	84
75th	91	90	92
90th	99	96	100
95th	105	100	107.25

Table 4: Association of Waist Circumference Categories and BMI Categories among overall Study Participants with Fisher–Freeman–Halton Exact Test (N = 528)

Waist Circumference (cm)	*Body Mass Index*						*Fisher–Freeman–Halton Test Statistic/p-value*
	<17.0 Severely thin	*17.1–18.4 Mildly thin*	*18.5–22.9 Normal*	*23.0–24.9 Overweight*	*≥25.0 Obese*	*Row Total (N)*	
≤72	2 (6.7%)	4 (13.3%)	13 (43.3%)	5 (16.7%)	6 (20.0%)	30	
73 - 75	4 (14.3%)	5 (17.9%)	10 (35.7%)	3 (10.7%)	6 (21.4%)	28	
76 - 80	8 (8.2%)	20 (20.4%)	46 (46.9%)	8 (8.2%)	16 (16.3%)	98	
81 - 85	14 (12.5%)	20 (17.9%)	44 (39.3%)	21 (18.8%)	13 (11.6%)	112	
86 - 91	9 (6.7%)	10 (7.5%)	52 (38.8%)	24 (17.9%)	39 (29.1%)	134	< 0.001
92 - 99	1 (1.3%)	2 (2.7%)	19 (25.3%)	14 (18.7%)	39 (52.0%)	75	
100 - 105	0 (0.0%)	0 (0.0%)	1 (3.8%)	5 (19.2%)	20 (76.9%)	26	
> 105	0 (0.0%)	0 (0.0%)	5 (20.0%)	4 (16.0%)	16 (64.0%)	25	
Column Total	38 (7.2%)	61 (11.6%)	190 (36.0%)	84 (15.9%)	155 (29.4%)	528 (100%)	

Table 5: Association of Waist Circumference Categories and BMI Categories among Male Participants with Fisher–Freeman–Halton Exact Test (N = 232)

Waist Circumference (cm)	*Body Mass Index*						*Fisher–Freeman–Halton Test Statistic/p-value*
	<17.0 Severely thin	*17.1–18.4 Mildly thin*	*18.5–22.9 Normal*	*23.0–24.9 Overweight*	*≥25.0 Obese*	*Row Total (N)*	
≤72	1 (7.7%)	3 (23.1%)	4 (30.8%)	2 (15.4%)	3 (23.1%)	13	
73 - 75	3 (23.1%)	2 (15.4%)	5 (38.5%)	2 (15.4%)	1 (7.7%)	13	
76 - 80	4 (9.8%)	8 (19.5%)	21 (51.2%)	1 (2.4%)	7 (17.1%)	41	
81 - 86	5 (8.5%)	6 (10.2%)	25 (42.4%)	14 (23.7%)	9 (15.3%)	59	
87 - 90	4 (8.0%)	3 (6.0%)	20 (40.0%)	11 (22.0%)	12 (24.0%)	50	0.05
91 - 96	2 (5.9%)	3 (8.8%)	11 (32.4%)	6 (17.6%)	12 (35.3%)	34	
97 - 100	0 (0.0%)	0 (0.0%)	3 (27.3%)	3 (27.3%)	5 (45.5%)	11	
> 100	0 (0.0%)	0 (0.0%)	2 (18.2%)	2 (18.2%)	7 (63.6%)	11	
Column Total	19 (8.2%)	25 (10.8%)	91 (39.2%)	41 (17.7%)	56 (24.1%)	232 (100%)	

Table 6: Association of Waist Circumference Categories and BMI Categories among Female Participants with Fisher–Freeman–Halton Exact Test (N = 296)

Waist Circumference (cm)	*Body Mass Index*						*Fisher–Freeman–Halton Exact Test (p-value)*
	<17.0 Severely thin	*17.1–18.4 Mildly thin*	*18.5–22.9 Normal*	*23.0–24.9 Overweight*	*≥25.0 Obese*	*Row Total (N)*	
≤72	1 (5.9%)	1 (5.9%)	9 (52.9%)	3 (17.6%)	3 (17.6%)	17	
73 - 75	1 (6.7%)	3 (20.0%)	5 (33.3%)	1 (6.7%)	5 (33.3%)	15	
76 - 80	4 (7.0%)	12 (21.1%)	25 (43.9%)	7 (12.3%)	9 (15.8%)	57	
81 - 84	9 (15.0%)	12 (20.0%)	24 (40.0%)	9 (15.0%)	6 (10.0%)	60	
85 - 92	4 (5.3%)	8 (10.7%)	24 (32.0%)	12 (16.0%)	27 (36.0%)	75	< 0.001
93 - 100	0 (0.0%)	0 (0.0%)	9 (20.5%)	7 (15.9%)	28 (63.6%)	44	
101 - 107.25	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (7.7%)	12 (92.3%)	13	
> 107.25	0 (0.0%)	0 (0.0%)	3 (20.0%)	3 (20.0%)	9 (60.0%)	15	
Column Total	19 (6.4%)	36 (12.2%)	99 (33.4%)	43 (14.5%)	99 (33.4%)	296 (100%)	

Table 7: Mean Waist Circumference According to Five ICMR BMI Categories Among Overall Participants (N = 528) (One-way ANOVA)

BMI category	*n*	*Mean waist circumference (cm) ± SD*	*F value*	*p value*
<17.0 (Severely thin)	38	74.84 ± 8.31		
17.1–18.4 (Mildly thin)	61	77.49 ± 7.56		
18.5–22.9 (Normal)	190	83.61 ± 8.47	84.62	<0.001
23.0–24.9 (Overweight)	84	89.94 ± 8.69		
≥25.0 (Obese)	155	98.31 ± 8.76		

Table 8: Mean Waist Circumference According to Five ICMR Body Mass Index Categories Among Male Participants (N = 232) (One-way ANOVA)

Body mass index category	*n*	*Mean waist circumference (cm) ± SD*	*F value*	*p value*
<17.0 (Severely thin)	19	76.11 ± 8.63		
17.1–18.4 (Mildly thin)	25	78.56 ± 7.56		
18.5–22.9 (Normal)	91	84.47 ± 7.71	35.91	<0.001
23.0–24.9 (Overweight)	41	89.61 ± 8.28		
≥25.0 (Obese)	56	95.52 ± 8.84		

and Body Mass Index categories was assessed using the Chi-square test. One-way Analysis of Variance (ANOVA) was performed to compare mean waist circumference across Body Mass Index categories. Binary logistic regression analysis was performed separately for males and females to estimate the odds of overweight and obesity across different waist circumference categories. Receiver Operating Characteristic (ROC) curve analysis was carried out to evaluate the diagnostic performance of waist circumference and waist-to-hip ratio in identifying overweight and obesity. The optimal waist circumference ranges obtained from these analyses, together with their corresponding Body Mass Index categories, were used to develop gender-specific colour zones for the proposed colour-coded waist belt. A p-value of <0.05 was considered statistically significant.

Results

Table 1 presents the distribution of the 528 study participants across the six selected villages according to sex and the total population of each village. The selected villages had a combined population of 16,821, from which 528 adults were included using proportionate allocation. Of the total participants, 232 (43.9%) were males and 296 (56.1%) were females. The highest number of participants was recruited from Ghonsla (125; 23.7%), followed by Sodang (105; 19.9%), Samanera (95; 18.0%), Tukral (75; 14.2%), Lambikhedi (68; 12.9%), and Shakkarkhedhi (60; 11.4%). Females outnumbered males in all six villages. The distribution of participants across villages reflects the proportionate allocation of the study sample according to the population size of the selected villages.

The study involved 528 participants, with 232 males (43.9%) and 296 females (56.1%). The mean age was 49.59 years, and the average Body Mass Index (BMI) was 22.60 ± 5.01 kg/m², indicating a normal range. Mean waist circumference was 86.20 ± 10.14 cm, hip circumference was 92.77 ± 10.28 cm, and the waist-to-hip ratio was 0.93 ± 0.08. These measurements provide baseline characteristics for analyzing the relationship between waist circumference and Body Mass Index -defined obesity.

Table 9: Mean Waist Circumference According to Five ICMR Body Mass Index Categories Among Female Participants (N = 296) (One-way ANOVA)

Body mass index category	*n*	*Mean Waist Circumference (cm) ± SD*	*F value*	*p value*
<17.0 (Severely thin)	19	73.58 ± 7.82		
17.1–18.4 (Mildly thin)	36	76.74 ± 7.55		
18.5–22.9 (Normal)	99	82.82 ± 8.94	66.84	<0.001
23.0–24.9 (Overweight)	43	90.26 ± 9.11		
≥25.0 (Obese)	99	99.89 ± 8.01		

Table 10: Binary Logistic Regression of Percentile-Based Waist Circumference Categories for Predicting Obesity Among Overall Participants (N = 528)

Waist circumference category (cm)	*Odds Ratio*	*95% CI*	*p-value*
≤72	1.00 (Reference)	—	—
73–75	1.09	0.24–4.93	0.89
76–80	0.78	0.23–2.69	0.64
81–85	0.53	0.15–1.86	0.23
86–91	1.64	0.52–5.19	0.31
92–99	4.33	1.32–14.25	0.004
100–105	13.33	2.93–60.76	<0.001
>105	7.11	1.69–29.95	0.002

Table 11: Binary Logistic Regression of Percentile-Based Waist Circumference Categories for Predicting Obesity Among Male Participants (N = 232)

Waist circumference category (cm)	*Odds Ratio*	*95% CI*	*p-value*
≤72	1.00 (Reference)	—	—
73–75	0.28	0.02–4.87	0.29
76–80	0.69	0.11–4.20	0.62
81–86	0.60	0.10–3.45	0.49
87–90	1.05	0.19–5.84	0.94
91–96	1.82	0.32–10.40	0.42
97–100	2.78	0.35–22.25	0.25
>100	5.83	0.70–48.33	0.05

Table 12: Binary Logistic Regression of Percentile-Based Waist Circumference Categories for Predicting Obesity Among Female Participants (N = 296)

Waist circumference category (cm)	*Odds Ratio*	*95% CI*	*p-value*
≤72	1.00 (Reference)	—	—
73–75	2.33	0.33–16.45	0.31
76–80	0.87	0.16–4.81	0.85
81–84	0.52	0.09–3.10	0.39
85–92	2.62	0.54–12.77	0.15
93–100	8.17	1.57–42.52	0.003
101–107.25	56.00	3.28–956.43	0.001
>107.25	7.00	1.02–47.84	0.01

The waist circumference distribution showed distinct variations between sexes. The 5th, 10th, and 25th percentiles were the same for both males and females (72 cm, 75 cm, and 80 cm). However, males had a higher median waist circumference (86 cm) than females (84 cm). Females also had higher upper percentiles, with the 75th, 90th, and 95th percentiles at 92 cm, 100 cm, and 107.25 cm, compared to 90 cm, 96 cm, and 100 cm for males. These results highlight the need for sex-specific waist circumference categories.

Table 4 presents the distribution of participants across waist circumference categories and the five ICMR Body Mass Index categories. The Fisher–Freeman–Halton Exact Test demonstrated a statistically significant association between waist circumference categories and Body Mass Index categories ($p < 0.001$) in the overall studied population, thereby indicating that higher waist circumference was strongly associated with higher Body Mass Index categories and lower waist circumference percentiles were strongly associated with low body mass index groups.

Among male participants, the proportion of obesity generally increased with increasing waist circumference and vice versa and this finding was statistically significant (Fisher–Freeman–Halton Exact Test, $p = 0.05$),

Among female participants, the prevalence of obesity increased markedly with increasing waist circumference, and thinness indices with decreasing waist circumference. The Fisher–Freeman–Halton Exact Test revealed a highly significant association between waist circumference categories and Body Mass Index categories ($p < 0.001$), indicating that increasing waist circumference was strongly associated with increasing Body Mass Index among females and vice versa.

Mean waist circumference rose with increasing Body Mass Index. Participants with severe thinness had a mean waist circumference of 74.84 ± 8.31 cm, while obese participants had 98.31 ± 8.76 cm. One-way ANOVA revealed a significant difference in waist circumference across Body Mass Index categories ($F = 84.62$, $p < 0.001$), highlighting a strong link between the mean waist circumference categories and BMI grades.

On gender specific exploration, among males, mean waist circumference increased steadily from 76.11 ± 8.63 cm in severely thin participants to 95.52 ± 8.84 cm among obese participants. The differences in mean waist circumference across BMI categories were statistically significant ($F = 35.91$, $p < 0.001$). These mean values were rounded up to their nearest mathematical comfort zones to establish the different waist circumference categories to predict the nutritional status.

Among females, mean waist circumference increased consistently with increasing Body Mass Index, ranging from 73.58 ± 7.82 cm in severely thin participants to 99.89 ± 8.01 cm among obese participants. One-way ANOVA demonstrated highly significant differences between Body Mass Index categories ($F = 66.84$, $p < 0.001$), indicating a strong positive relationship between waist circumference and BMI among females and these mean values were used to serve as the basis of deciding the different categories of nutritional status based on waist circumference measurements in women.

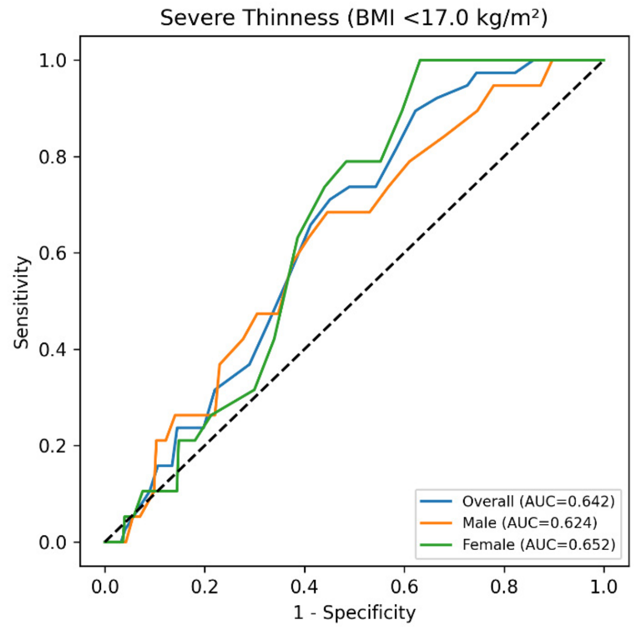
Binary logistic regression revealed that higher waist circumference percentiles were linked to increased obesity odds. Participants with waist circumferences between 92 and 99 cm had significantly higher odds (OR = 4.33, 95% CI: 1.32–14.25; p = 0.004), while those with 100 to 105 cm had the highest odds (OR = 13.33, 95% CI: 2.93–60.76; p < 0.001). Those exceeding 105 cm also showed increased odds (OR = 7.11, 95% CI: 1.69–29.95; p = 0.002). Lower categories showed no significant associations.

Among males, the odds of obesity increased with higher waist circumference categories, though none were statistically significant. The >100 cm category had nearly six times the odds of obesity (OR = 5.83, 95% CI: 0.70–48.33; p = 0.05), indicating a borderline significant association. Limited precision is suggested by wide confidence intervals due to smaller sample sizes in extreme categories.

Higher waist circumference is strongly linked to obesity in females. Those with a waist circumference of 93-100 cm have over eight times the odds of obesity (OR = 8.17, p = 0.003), while women measuring 101-107.25 cm have the highest odds (OR = 56.00, p = 0.001). Even those with a waist circumference over 107.25 cm show significantly increased odds (OR = 7.00, p = 0.019). This indicates that waist circumference is a strong predictor of obesity in women.

Figures 1 and 2 illustrate the receiver operating characteristic (ROC) curves evaluating the ability of waist circumference to identify severe thinness (BMI <17.0 kg/m²) and their corresponding gender specific waist circumference(WC) categories (bands) (Male < 74 cm, Female ≤76 cm) in the studied participants. The ROC analysis showed comparable diagnostic accuracy between BMI and gender specific WC ranges for predicting severe undernutrition or thinness (AUC at 0.64, 0.62, and 0.65 for overall, male, and female participants, respectively).

The Figures 3and 4 present the ROC curves of the proposed sex-specific waist circumference categories for screening severe undernutrition. The proposed cut-offs were ≤74 cm for males and ≤76 cm for females. The ROC analysis demonstrated fair discriminatory ability, with an AUC of 0.624 among males, 0.652 among females, and 0.640 for the overall study population. The female curve showed slightly better discrimination than the male curve. Overall, the ROC curves remained above the reference line, indicating that the proposed waist circumference cut-offs performed better than chance in identifying individuals with severe undernutrition. However, the moderate AUC values suggest that these cut-offs should be considered screening indicators rather than diagnostic criteria.



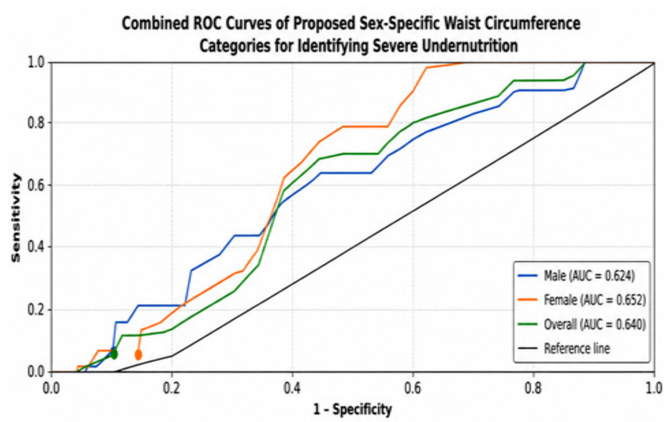
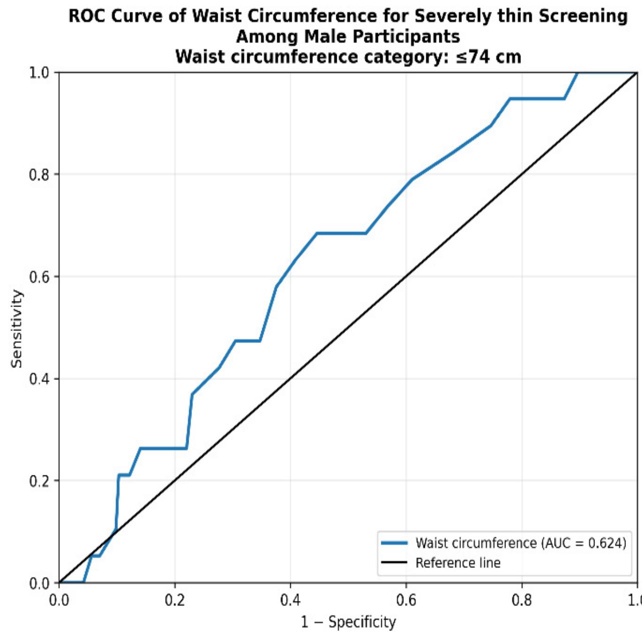


Figure 1 and 2: Receiver Operating Characteristic (ROC) Curves for Identifying Severe undernutrition (BMI <17.0 kg/m²) Among Overall, Male, and Female Participants Vs Combined Receiver Operating Characteristic (ROC) Curves of Proposed Sex-Specific Waist Circumference Categories for Severe Undernutrition

Figures 5 and 6 present the ROC curves for identifying mild thinness (BMI 17.1–18.4 kg/m²) and their corresponding waist circumferences. The AUC in both the circumstances were near equal and well above the 0.69 range, indicating good predictive potential.

The Figure 7 presents the ROC curves of the proposed sex-specific waist circumference categories for screening mild undernutrition. The proposed waist circumference



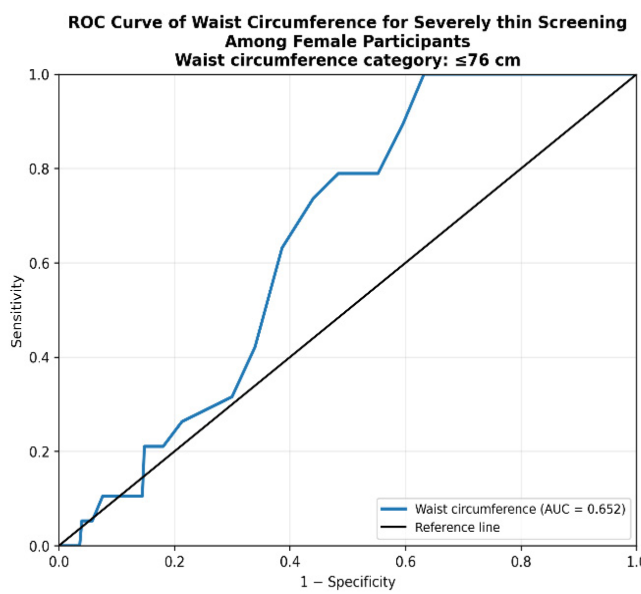
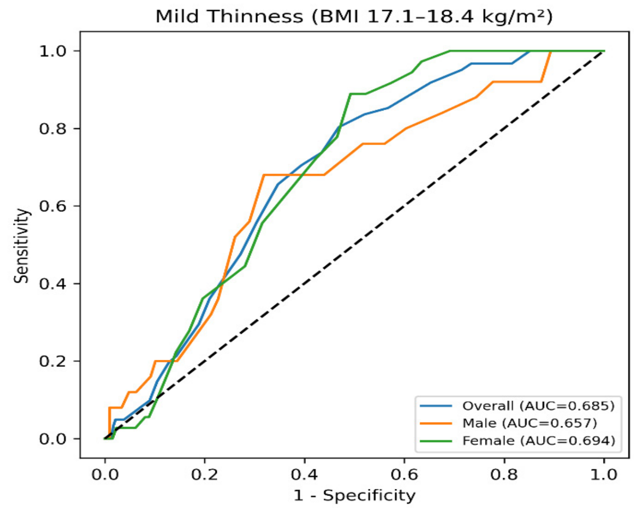


Figure 3 and 4: Receiver Operating Characteristic (ROC) Curve of Proposed Male and Female Waist Circumference Categories for Severe Undernutrition Screening (Male < 74 cm, Female ≤76 cm)

ranges were 74–77 cm for males and 76–79 cm for females. The ROC analysis demonstrated fair discriminatory ability, with an AUC of 0.657 among males, 0.694 among females, and 0.679 for the overall study population. The female curve showed slightly better discriminatory performance than the male curve. The curves remained above the reference line, indicating better-than-chance discrimination. However, the moderate AUC values and relatively limited sensitivity indicate that these proposed waist circumference categories should be regarded as



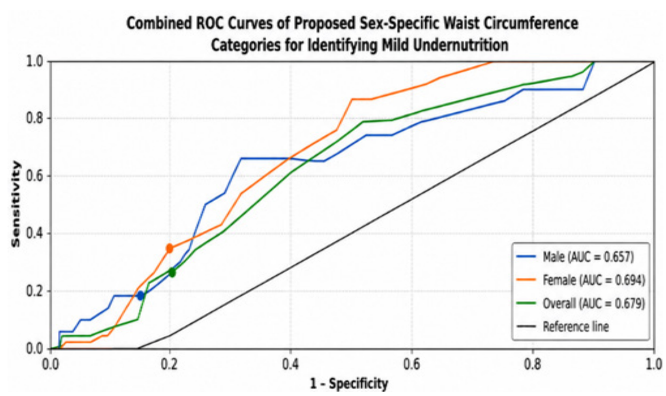


Figure 5 and 6: Receiver Operating Characteristic (ROC) Curves for Identifying Mild Undernutrition (BMI 17.1–18.4 kg/m²) Among Overall, Male, and Female Participants Vs. Combined Receiver Operating Characteristic (ROC) Curves of Proposed Sex-Specific Waist Circumference Categories for Mild Undernutrition Screening

preliminary community screening indicators rather than diagnostic criteria for mild undernutrition.

The receiver operating characteristic (ROC) analysis demonstrated that waist circumference had acceptable discriminatory ability for identifying obesity among overall and both male and female participants, with an area under the curve (AUC) of 0.71, 0.65 and 0.75, respectively (95% CI: 0.660–0.764; $p < 0.001$). The ROC curve indicates that waist circumference is a useful anthropometric measure for community-based obesity screening.

Figure 8 shows the ROC curves evaluating the diagnostic performance of waist circumference for identifying overweight (BMI 23.0–24.9 kg/m²). Waist circumference demonstrated acceptable discriminatory ability among the overall study population as well as among male and female participants. Increasing

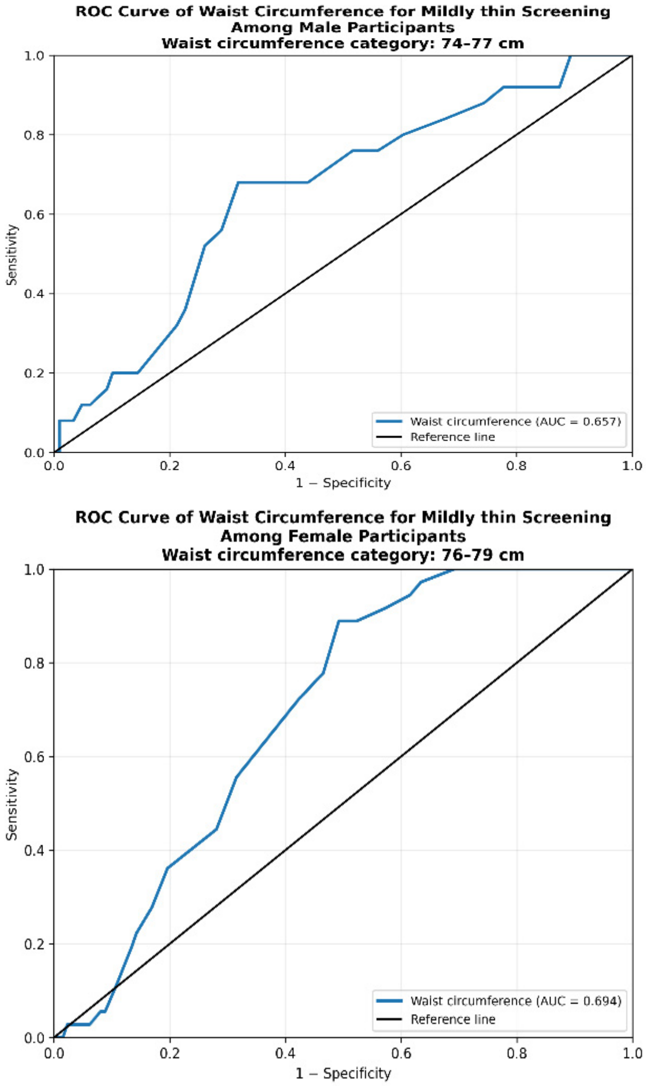
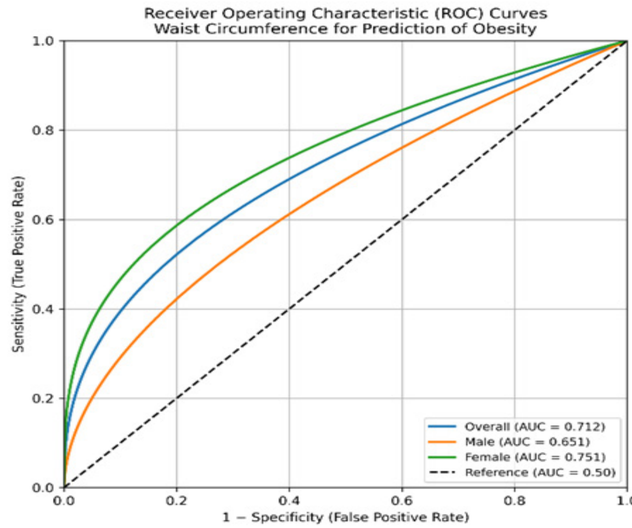


Figure 7 and 8: Receiver Operating Characteristic (ROC) Curve of Proposed Waist Circumference Categories for Mild Undernutrition Screening (Male 74- 77 cm, Female 76- 79 cm)



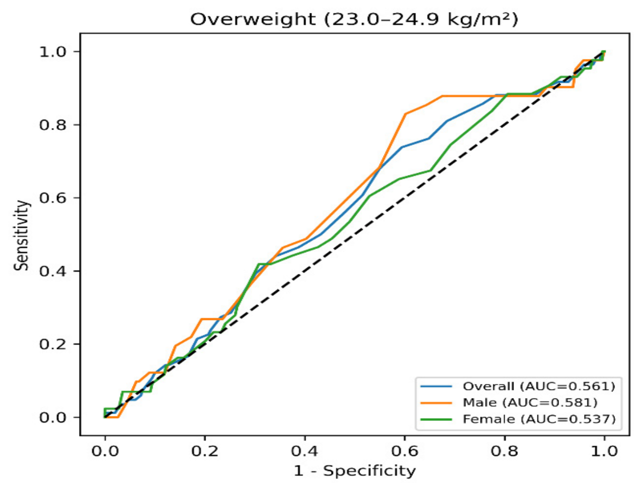


Figure 8: Receiver Operating Characteristic (ROC) Curves for Identifying Overweight (BMI 23.0–24.9 kg/m²) Among Overall, Male, and Female Participants

waist circumference was associated with a higher probability of overweight, supporting its usefulness as a practical anthropometric indicator for community-based screening. The diagnostic performance was generally comparable between sexes, although minor differences in AUC values reflected sex-specific fat distribution patterns.

The Figure 9 presents the ROC curves of the proposed sex-specific waist circumference categories for screening overweight. The proposed waist circumference ranges were 83–90 cm for males and 84–90 cm for females. The ROC analysis demonstrated acceptable discriminatory ability for identifying individuals with overweight. The curves remained above the reference line, indicating that the proposed waist circumference ranges performed better than chance in distinguishing overweight participants. Overall, these findings support the potential utility of the proposed sex-specific waist circumference categories as a simple and practical screening approach for overweight in community settings, although they should be considered screening indicators rather than diagnostic criteria.

Figures 10 and 11 present the ROC curves assessing the diagnostic performance of waist circumference for identifying obesity (BMI ≥25.0 kg/m²) and their corresponding waist circumference counterparts. In terms of AUC representations, both indices recorded valid and near-equal values.

The Figure 12 presents the ROC curves of the proposed sex-specific waist circumference categories for screening obesity. The proposed waist circumference

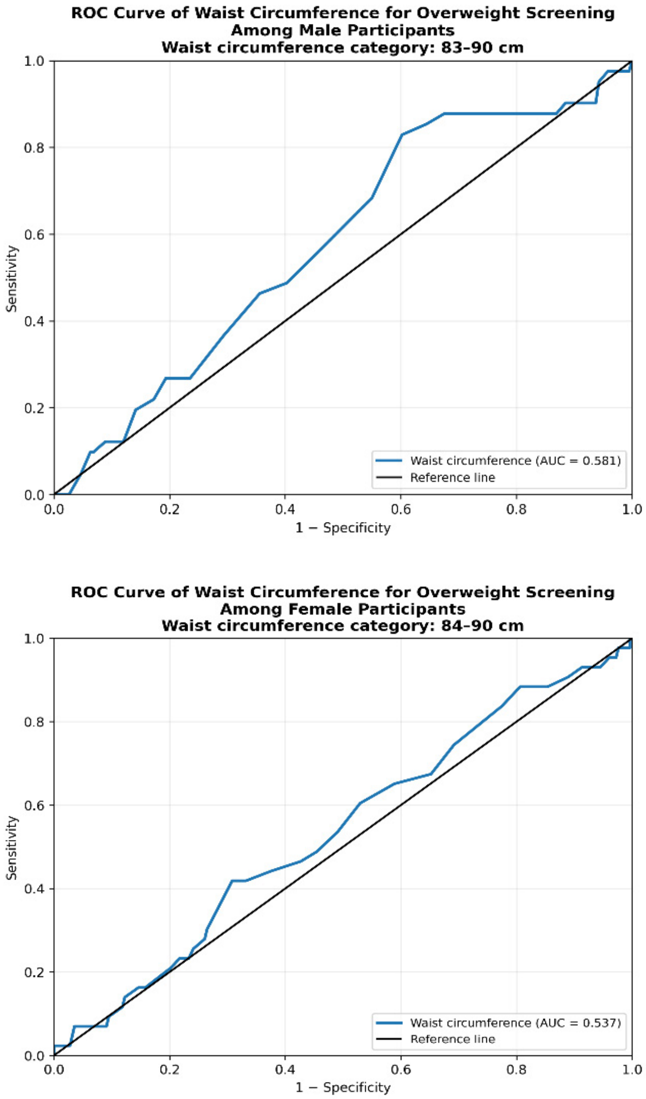


Figure 9: Receiver Operating Characteristic (ROC) Curve of Proposed Waist Circumference Categories for Overweight Screening (Male 83-90 cm, Female 84- 90 cm)

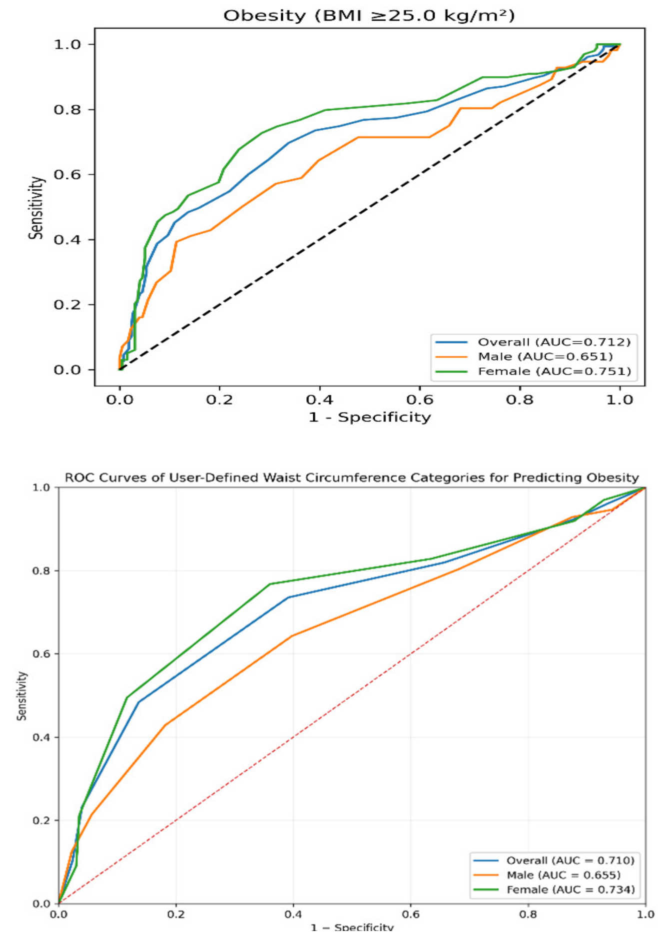


Figure 10 and 11: Receiver Operating Characteristic (ROC) Curves of Waist Circumference for Identifying Obesity (BMI ≥25.0 kg/m²) Among Overall, Male, and Female Participants Vs. Receiver Operating Characteristic (ROC) Curves of Proposed Waist Circumference Categories for Identifying Obesity Among Overall, Male, and Female Participants

ranges were 90–100 cm for males and 90–96 cm for females. The ROC analysis demonstrated acceptable discriminatory ability for identifying individuals with obesity. The curves remained above the reference line, indicating better-than-chance discrimination. The proposed waist circumference categories therefore show potential as a simple, practical, and low-cost screening approach for obesity in community settings, although they should be regarded as screening indicators rather than diagnostic criteria.

The ROC curve for the proposed waist circumference category for obesity screening (male >100 cm and female >96 cm) could not be generated because the frequency of participants falling within this category was low, resulting in insufficient observations for reliable ROC analysis.

Designing the Tool

Encouraged by the findings, we were tempted to design a public health innovative tool for nutritional Screening in Indian adults and named it as 'The Mishra's Metabolic & Cellular Optimisation Risk Evaluation Dual Tape' (M-CORE dual tape). The one-way ANOVA mean values served as the category identifiers, and a sex-specific six-colour-coded WC measuring dual tape(belt) was developed. Separate waist circumference cut-offs for males and females were classified into Purple, Blue, Green, Yellow, Orange, and Red zones, representing undernutrition(Severely thin and Mildly thin), normal, overweight and obese (Obesity grade 1 and Obesity

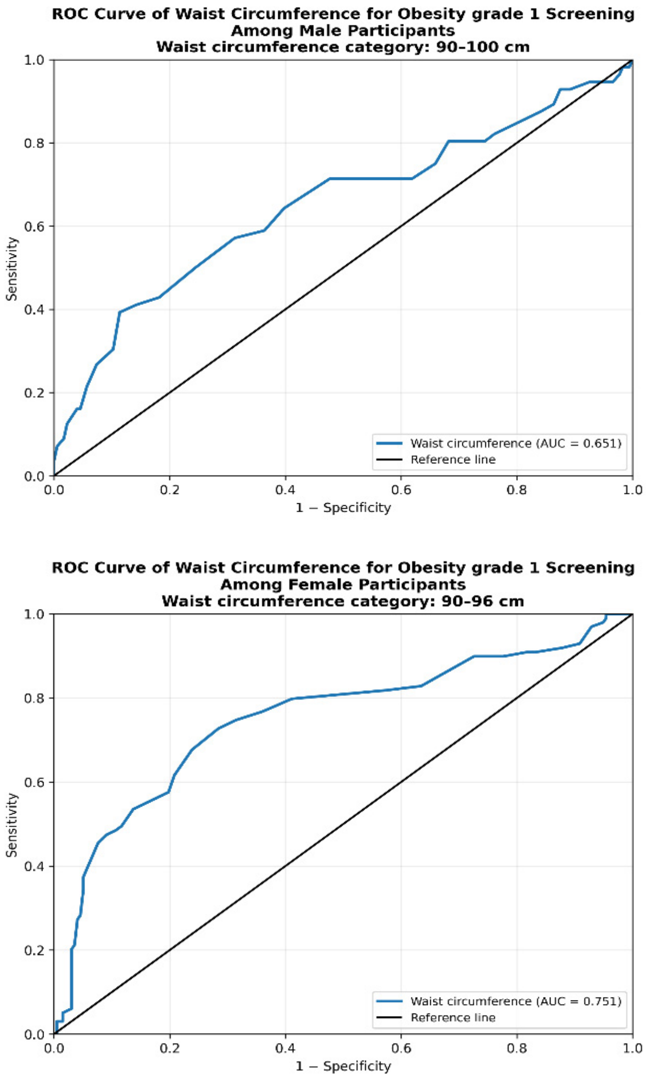


Figure 12: Receiver Operating Characteristic (ROC) Curve of Proposed Waist Circumference Categories for Obesity Screening (Male 90-100 cm, Female 90- 96 cm)

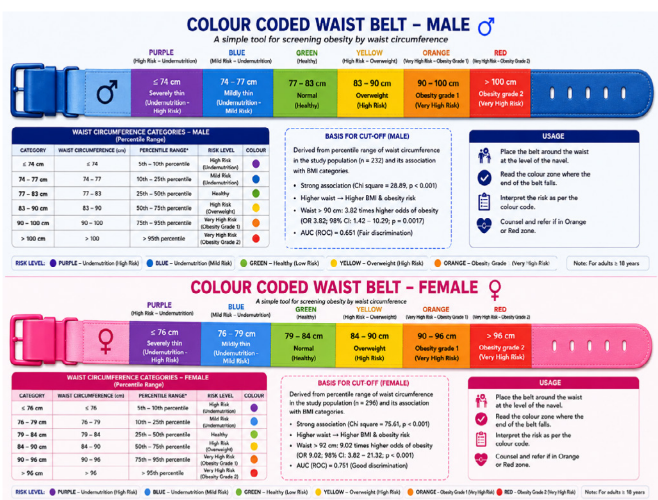


Figure 13 and 14: Preliminary look of the product.

Table 13: Proposed 'The Mishra's Metabolic & Cellular Optimisation Risk Evaluation Dual Tape' (M-CORE dual tape) reading for adult males

Colour	*Waist circumference (cm)*	*Predominant body mass index category*	*Interpretation*
Purple	≤74	Severely thin	Undernutrition (High Risk)
Blue	74–77	Mildly thin	Undernutrition (Mild Risk)
Green	77–83	Normal	Healthy
Yellow	83–90	Overweight	Overweight / High Risk
Orange	90-100	Obesity grade 1	Obesity / Very High Risk
Red	>100	Obesity grade 2	Obesity / Very High Risk

Table 14: Proposed 'The Mishra's Metabolic & Cellular Optimisation Risk Evaluation Dual Tape' (M-CORE dual tape) reading for adult females

Colour	*Waist circumference (cm)*	*Predominant body mass index category*	*Interpretation*
Purple	≤76	Severely thin	Undernutrition (high risk)
Blue	76–79	Mildly thin	Undernutrition (mild risk)
Green	79–84	Normal	Healthy
Yellow	84–90	Overweight	Overweight/ high risk
Orange	90-96	Obesity grade 1	Obesity/very high risk
Red	>96	Obesity grade 2	Obesity/very high risk

grade 2). The tape shall have prints on both sides, one representing male and the other for female candidates with their respective insignia and cutoff values. The proposed belt shall serve as a simple, easy-to-use, and practical tool for rapid community and clinic-based nutritional screening without requiring a cumbersome BMI calculation.

Discussion

The present study demonstrated that WC categories associate well with their corresponding Body Mass Index -defined nutritional categories(grades). Waist circumference increased progressively across BMI categories, while higher waist circumference percentile groups were associated with a greater prevalence and higher odds of obesity and vice versa. These findings support previous evidence that Asian Indians are predisposed to increased abdominal and visceral adiposity even at relatively lower Body Mass Index values, making waist circumference an important anthropometric indicator beyond Body Mass Index alone[1-6,14-18] .

The percentile distribution of waist circumference revealed distinct sex-specific differences. Although the lower percentile values (5th, 10th and 25th percentiles) were identical in males and females, females demonstrated higher values at the upper percentiles (75th, 90th and 95th percentiles). These findings suggest greater variability in abdominal fat accumulation among women at higher levels of adiposity. Similar sex-related differences in body fat distribution have been described previously, where hormonal and metabolic factors influence visceral fat deposition differently in men and women [18]. Consequently, sex-specific waist circumference thresholds have been recommended for more accurate assessment of obesity and cardiometabolic risk [19].

A significant association was observed between waist circumference percentile categories and Body Mass Index classification among overall participants ($\chi^2 = 122.40$, $p < 0.001$), with similar statistically significant associations among males ($\chi^2 = 41.15$, $p < 0.05$) and females ($\chi^2 = 87.66$, $p < 0.001$). The proportion of obese individuals increased progressively across successive waist circumference categories, whereas lower percentile groups were predominantly composed of participants with normal BMI or undernutrition. These findings indicate that increasing waist circumference closely parallels increasing adiposity and decreasing WC associates strongly with one's thinness status. Similar observations have been reported among Indian adults, where the combined assessment of Body Mass Index and waist circumference substantially improved both undernutrition and obesity classification compared with Body Mass Index alone [20,21]. Likewise, the International Day for the Evaluation of Abdominal Obesity (IDEA) study demonstrated a strong association between waist circumference and cardiometabolic disorders across diverse populations [22].

Binary logistic regression further strengthened these findings. Participants with waist circumference between 92 and 99 cm had more than four-fold higher odds of obesity, while those with waist circumference between 100 and 105 cm had over thirteen-fold higher odds compared with the reference category. Among females, the association was even stronger, with women having waist circumference between 101 and 107.25 cm demonstrating markedly increased odds of obesity. Although increasing odds were also observed among males, statistical significance was not consistently achieved because of wider confidence intervals in the highest waist circumference categories. Previous studies have similarly reported that increasing waist circumference thresholds are independently associated with obesity and cardiometabolic risk, supporting the use of waist circumference as a reliable screening tool [23-26] .

One-way analysis of variance demonstrated a significant progressive increase in mean waist circumference across all Body Mass Index categories among the overall population as well as in both sexes ($p < 0.001$). Mean waist circumference increased from 74.84 cm among severely thin individuals to 98.31 cm among obese participants. Similar increasing trends were observed among males and females, confirming a strong positive relationship between waist circumference and BMI. These findings are consistent with previous systematic reviews demonstrating that waist circumference closely reflects increasing adiposity while providing additional information regarding central obesity that cannot be captured by Body Mass Index alone [27].

Receiver operating characteristic analysis demonstrated acceptable overall discriminatory performance of waist circumference for identifying both under- and overnutrition status.(AUC = 0.712; 95% CI: 0.660–0.764; $p < 0.001$). Sex-specific analysis showed fair discrimination among males (AUC = 0.651) and good discrimination among females (AUC = 0.751), suggesting that waist circumference performs better as a screening tool for obesity among women in the present population. Similar findings have been reported by Tutunchi et al. and Macek et al., who demonstrated acceptable diagnostic accuracy of waist circumference for predicting overweight and obesity[23,24] . Furthermore, Castle et al. reported that sex-specific anthropometric thresholds improve the identification of dysglycaemia and obesity, further supporting the development of separate waist circumference categories for men and women.

Overall, the present findings indicate that percentile-based waist circumference categories closely correspond with Body Mass Index-defined nutritional categories (ranges) spanning from severe thinness to obesity type 2 as per ICMR guidelines. Thus, adopting a WC-based guideline for overall nutritional assessment may provide an inexpensive, rapid, and practical method for community- and clinic-based screening. Unlike BMI, waist circumference directly reflects abdominal adiposity and requires minimal equipment, no conversion of metrics and no mathematical calculation, thus making it particularly suitable for field surveys, primary healthcare settings, busy hospital(clinical) settings and national level screening programmes. The proposed sex-specific colour-coded WC measuring tape(belt) translates these findings into a simple visual tool that can facilitate early identification of underweight, overweight and obese conditions in community and clinical settings, consistent with current Indian recommendations for obesity management and screening[28-34] .

Conclusion

The present study demonstrated that waist circumference is a simple, reliable, and practical anthropometric measure for identifying all grades of nutritional defects among Indian adults. Waist circumference showed a strong positive association with Body Mass Index categories, with progressively increasing waist circumference across increasing Body Mass Index categories, and higher waist circumference percentile groups were associated with significantly greater odds of obesity. Receiver operating characteristic analysis further demonstrated acceptable discriminatory ability of waist circumference for detecting nutritional abnormalities, with better diagnostic performance observed among females than males, supporting the need for sex-specific waist circumference thresholds.

Based on these findings, a gender-specific colour-coded waist circumference measuring tape- 'The Mishra's Metabolic & Cellular Optimisation Risk Evaluation Dual Tape' (M-CORE dual tape) is proposed as a public health and clinical innovation Tool for nutritional Screening in Indian adults. The proposed tool shall enable rapid interpretation of undernutrition and obesity risk without the need for Body Mass Index calculation, weighing scales, stadiometers, or reference charts, making it particularly suitable for primary healthcare and daily clinical settings, field surveys, and large-scale community screening programmes. Owing to its simplicity, low cost, portability, and ease of use, this colour-coded tool shall have the potential to facilitate early identification of individuals at increased nutritional risk and promote timely lifestyle counselling and referral.

Further multicentric studies involving diverse geographical regions and ethnic populations are warranted to externally validate the proposed tool, in order to establish nationally representative cut-off values, and evaluate its feasibility, acceptability, diagnostic performance, and cost-effectiveness before large-scale implementation in routine health practice.

Strengths and Limitations

The present study is among the first in India to develop a gender-specific colour-coded WC dual tape(belt) as a practical health innovation for community and clinic-based nutritional screening tool. The study was community-based, included a relatively large sample of adults, and used standardized anthropometric measurements by trained investigators. The proposed colour zones were developed based on separate percentile-based colour zones for males and females using complementary statistical methods, including the association between waist circumference and BMI, logistic regression, and ROC analysis, thereby providing a robust evidence-based foundation for the screening tool. However, the cross-sectional design precludes causal inference, and the findings from a single district may limit generalizability. Body Mass Index was used as the reference standard instead of direct body fat assessment methods such as DEXA or CT. Although the proposed colour-coded tool demonstrated promising diagnostic performance, further multicentric validation and evaluation of its operational feasibility, acceptability, and effectiveness in routine healthcare settings are required before large-scale implementation.

Conflict of Interest

None declared.

Ethical Considerations

The study was conducted after obtaining approval from the Institutional Ethics Committee of R.D. Gardi Medical College, Ujjain with reference no. 01/2025.

Written informed consent was obtained from all participants before enrolment in the study. Confidentiality and anonymity of the participants were maintained throughout the study.

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