Waist circumference and waist-hip ratio as predictors of type 2 diabetes mellitus in the Nepalese population of Kavre District

A Shah,[1] S Bhandary,[2] SL Malik,[1] P Risal[3] and R Koju[4]

[1]Department of Physiology, Kathmandu University School of Medical Sciences, Chaukot, Panauti-1, Kavre, Nepal, [2]Department of Community Health Sciences, Patan Academy of Health Sciences, Patan Hospital, Nepal, [3]Department of Biochemistry, Kathmandu University School of Medical Sciences, Chaukot, Panauti-1, Kavre, Nepal and [4]Department of Medicine, Kathmandu University School of Medical Sciences, Chaukot, Panauti-1, Kavre, Nepal

Corresponding author: Mr. Amin Shah, Lecturer, Department of Physiology, Kathmandu University School of Medical Sciences, Chaukot, Panauti-1, Kavre, Nepal; e-mail: aaminshah@hotmail.com

ABSTRACT

The objective of the present study was to find out WHR and WC as predictor of Type 2 DM in the population of Kavre district of Nepal. Sixty-five "known type 2 diabetic" and Thirty-five "self-reported non-diabetic" subjects above thirty years of age were included in the present study. Height, Weight, Waist Circumference and Hip Circumference were recorded for every subject. BMI and WHR were calculated by the standard formula. The data was analyzed using SPSS Evaluation Version 15.0 and STATA Special Edition Version 8.2. Our results showed that the optimal cut-off values for WHR, WC. BMI and age in female are 0.87, 0.85cms, 21.40 kg/m^2 and 40 years respectively and for male the respective values are 0.96, 0.87cms, 23.63 kg/m^2 and 44 years. In female, age (82.9%) is the strongest predictor followed by WHR (78.1%), WC (70.2%) and least for BMI (55.0%) whereas for male WC (87.0%) is the strongest followed by WHR (81.6%), BMI (68.5%) and least for age (64.6%) using Receiver Operating Characteristic (ROC) curves. Optimum sensitivity and specificity obtained from the ROC curves corresponded to these cutoff values and area under curve for their predictive ability. The current study showed that the WC and WHR are the best predictors of type 2 DM in both male and female population of Kavre district.

Keywords: BMI, WC, WHR, Type 2 DM, Kavre district.

INTRODUCTION

Obesity is defined as an excess body fat resulting from a chronic imbalance between food intake and energy expenditure.[1] It is a rapidly growing health problem in both developed and developing countries .From clinical point of view, visceral adipose tissue is known to generate diabetogenic substances[2] and may provide more information than total fat for diagnostic evaluation. Visceral obesity which is approximated by Waist Circumference (WC) or Waist-Hip Ratio (WHR) is typically seen in overweight and obese men. It is closely linked with insulin resistance, hypertension and dyslipidaemia, and causally related to increased risk of type 2 diabetes mellitus (DM) and cardiovascular disease.[3,4]

The various risk factors for the development of type 2 DM are obesity, ethnicity, sedentary life style, sex, family history, hypertension and smoking. However there is now an overwhelming evidence from experimental, epidemiological and intervention studies that obesity is a major risk factor for Type 2 DM among all risk factors.

High Waist Circumference (WC), Waist-Hip Ratio (WHR), Body Mass Index (BMI) and age are risk factors as well as predictors of type 2 DM. The higher risk of type 2 DM in people with a high WHR and WC has been attributed to increased visceral fat accumulation.

Among various anthropometric measurements used to measure the obesity, WC and WHR have been used as measures of visceral obesity whereas BMI as general obesity.[5] Clinical evidence suggests that WC and WHR are better predictors of obesity and type 2 DM. However, such studies have not yet been conducted so far in Nepal. So this study intends to determine WHR and WC as predictor of Type 2 DM.

MATERIALS AND METHODS

Selection of subjects: Sixty-five type 2 diabetic and thirty-five non-diabetic subjects of Kavre district above thirty years of age attending the Kathmandu University Teaching Hospital (KUTH) were included in the study. The diabetic subjects were already "known type 2 diabetic patients" diagnosed clinically by specialist. The diagnosis was made by a typical presentation and course with evidence of possible diabetic complications (vision problems, retinopathy, impotence, renal dysfunction, peripheral neuropathy or frequent infection) along with the laboratory findings as per American Diabetes Association (ADA) criteria:[6]

Table-1: Descriptive statistics and t-test of independence for age, BMI, waist circumference and waist hip ratio by gender and diabetic status

	Gender of the subject	Diabetic status	Mean	Standard Deviation	N	p-value
Age of the subject	Male	Diabetic	51.7368	11.87931	38	> 0.05
		Non diabetic	45.1333	15.47286	15	
		Total	49.8679	13.18659	53	
	Female	Diabetic	55.2963	13.57264	27	< 0.0001
		Non diabetic	40.0000	12.61995	20	
		Total	48.7872	15.11109	47	
	Total	Diabetic	53.2154	12.63118	65	< 0.0001
		Non diabetic	42.2000	13.93641	35	
		Total	49.3600	14.06157	100	
Body Mass Index	Male	Diabetic	24.3195	3.46042	38	> 0.05
		Non diabetic	22.0741	3.70081	15	
		Total	23.6840	3.64012	53	
	Female	Diabetic	23.0714	3.37166	27	> 0.05
		Non diabetic	23.1505	5.20804	20	
		Total	23.1051	4.19884	47	
	Total	Diabetic	23.8011	3.45330	65	> 0.05
		Non diabetic	22.6892	4.59228	35	
		Total	23.4119	3.90334	100	
Waist Circumference	Male	Diabetic	87.1053	11.15200	38	< 0.001
		Non diabetic	77.5333	5.90238	15	
		Total	84.3962	10.80837	53	
	Female	Diabetic	82.8889	14.84104	27	> 0.05
		Non diabetic	76.9500	11.21782	20	
		Total	80.3617	13.61174	47	
	Total	Diabetic	85.3538	12.87492	65	< 0.001
		Non diabetic	77.2000	9.20614	35	
		Total	82.5000	12.31038	100	
Waist Hip Ratio	Male	Diabetic	1.0033	.14838	38	< 0.0001
		Non diabetic	.9033	.04469	15	
		Total	.9750	.13517	53	
	Female	Diabetic	.9484	.07227	27	< 0.01
		Non diabetic	.8781	.05919	20	
		Total	.9185	.07506	47	
	Total	Diabetic	.9805	.12487	65	< 0.001
		Non diabetic	.8889	.05423	35	
		Total	.9484	.11410	100	

Note: Analysis performed using SPSS Evaluation Version 15.0.

- Fasting plasma glucose >= 126mg/dL (7.0 mmol/L)
- Random plasma >= 200mg/dL (11.1 mmol/L)
- Postprandial plasma glucose>=200 mg/dL (11.1 mmol/L)

The laboratory findings were confirmed on repeated testing on another day. The non-diabetic subjects were the "self reported non-diabetic individuals" without the classical symptoms and possible complications of DM who were the relatives of others patients attending KUTH. Informed consent was obtained from all study subjects.

Selection of variable: Height, Weight, BMI, WC and WHR were measured following the standard procedure.

Anthropometric measurements:

Anthropometric measurements were taken with subjects in light clothing and without shoes. Height and weight were measured using calibrated stadiometer and portable weighing machine respectively. The height and weight were recorded to the nearest centimeters and kilograms respectively. BMI was calculated by dividing weight (kg) by square of height (m^2).

Waist and hip circumference were measured with a nonstretchable plastic tape. Waist circumference was measured as the minimum horizontal girth between costal margins and iliac crests at the end of normal expiration. The waist circumference was recorded nearest to centimeter. Hip circumference was measured as the maximum circumference of the buttocks over the greater trochanters. The hip circumference was recorded nearest to centimeter. Waist to Hip ratio (WHR) was calculated as Waist circumference (cm) divided by Hip circumference (cm).

STATISTICAL ANALYSIS

Data entry and analysis were done using Statistical Package for Social Sciences (SPSS) Evaluation Version 15.0 and STATA Special Edition Version 8.2. At first, descriptive statistics (mean and standard deviation) of the four predictors of type 2 DM, that is, age, BMI, WC and WHR of the subjects, were computed. Later, disaggregated analysis of these four predicting variables was carried out for gender and then for diabetic status. Student's Independent t-test and its associated p-values were used to confirm the statistical validity of the obtained descriptive statistics. After that, Receiver Operating Characteristic (ROC) curves[7] were used to find and confirm the optimum cut-off values of age, BMI, WC and WHR associated with the risk of developing type 2 DM for male as well as female subjects. Optimum efficiency and Youden's Index[8] were also used to find out the optimum cut-off values of the predicting variables including the sensitivity, specificity, likelihood ratios and area under curve of each of the variable under consideration.

RESULTS

The present study is based on the 100 sample subjects: 53 males and 47 females. There were 65 diabetic and 35 non-diabetic subjects. Table-1 presents the descriptive statistics for age, BMI, WC and WHR by gender and controlled by diabetic status. The reference range ($\overline{X} \pm Z_{\alpha} * \sigma$), which roughly corresponds to ($\overline{X} \pm 2\sigma$) for samples with more than 30 subjects, gives the dispersion of a quantitative variable. It corresponds to 95% dispersion from the arithmetic mean.

The reference age range for male, female and total subjects were found 49.87 ± 26.37, 49.36 ± 28.12, 48.79 ± 30.22 and 49.36±28.12 years respectively. After controlling for diabetic status, reference age for the diabetic and non-diabetic female subjects was found 55.30 ± 27.14 years and 40.00 ± 25.24 years respectively and for diabetic and non-diabetic male subjects it was found 51.74 ± 23.76 years and 45.13 ± 30.94 years .The reference BMI range for male, female and total subjects were found 23.68 ± 7.2, 23.11 ± 8.4 and 23.41 ± 7.8 kg/m^2 respectively. After controlling for diabetic status, reference BMI for the diabetic and non-diabetic female subjects was found 23.07 ± 6.74 kg/m^2 and 23.15 ± 10.40 kg/m^2 respectively and for diabetic and non-diabetic male subjects it was found 24.32 ± 7.0 kg/m^2 and 22.07 ± 7.4 kg/m^2.

The reference WC range for male, female and total subjects were found 84.40 ± 21.62, 80.36 ± 27.24 and 82.50 ± 24.62 centimeters (cms) respectively. After controlling for diabetic status, reference WC for the diabetic and non-diabetic female subjects was found 82.89 ± 29.68 cms and 76.95 ± 22.44 cms respectively and for diabetic and non-diabetic male subjects it was found 87.11 ± 22.30 cms 77.53 ± 11.80 cms. The reference WHR range for male, female and total subjects were found 0.975 ± 0.28, 0.919 ± 0.16 and 0.948 ± 0.22 respectively. After controlling for diabetic status,

Table-2: Optimal cut-off points for various indicators related to female characteristics

Associated values for the optimum cut-off points:	Female			
	WHR	WC	BMI	AGE
	Optimum cut-off point			
	> = 0.87	> = 85	> = 21.40	> = 40
Sensitivity	88.9%	59.3%	74.1%	96.3%
Specificity	55.0%	80.0%	50.0%	60.0%
Efficiency	74.5%	68.1%	63.8%	80.8%
LR +	1.9753	2.963	1.4815	2.4074
LR -	0.202	0.5093	0.5185	0.0617
Youden index	0.4389	0.3926	0.2407	0.5630
Area under curve	0.7815	0.7019	0.55	0.8296
p-value (AUC)	< 0.005	< 0.05	> 0.05	< 0.001

Note: AUC= Area under curve LR = Likelihood Ratio
Note: Analysis performed using STATA SE V8.2.

Table-3: Optimal cut-off points for various indicators related to male characteristics

Associated values for the optimum cut-off points:	Male			
	WHR	WC	BMI	AGE
	Optimum cut-off point			
	> =0.96	> = 87	>=23.63	> = 44
Sensitivity	57.9%	68.4%	63.2%	78.9%
Specificity	93.3%	93.3%	73.3%	60.0%
Efficiency	67.9%	75.5%	66.0%	73.6%
LR +	8.6842	10.2632	2.3684	1.9737
LR -	0.4511	0.3383	0.5024	0.3509
Youden index	0.5122	0.6175	0.3649	0.3895
Area under curve	0.8158	0.8702	0.6851	0.6465
p-value (AUC)	< 0.001	<0.0001	< 0.05	> 0.05

Note: AUC= Area under curve LR = Likelihood Ratio
Note: Analysis performed using STATA SE V8.2.

reference WHR for the diabetic and non-diabetic female subjects was found 0.948 ± 0.14 and 0.878 ± 0.08 respectively and for diabetic and non-diabetic male subjects it was found 1.00 ± 0.30 and 0.903 ± 0.08.

Table-2 and 3 show the result obtained from the ROC curve analysis for WHR, WC, BMI and age of the subject. It shows the "optimal" cut-off points where sensitivity, specificity and positive likelihood ratios were maximized. It also presents the corresponding negative likelihood ratios, efficiency of the diagnostic test and the Youden's Index. It also shows the area under ROC curves and associated p-value for underlying characteristics of the subject.

Table-2 shows that WHR, WC, BMI and age of the female subjects covered 78.1%, 70.2%, 55.0% and 82.9% areas under ROC curve respectively with significant p-values except for the BMI. The risk of developing type 2 DM for female subjects increased with the age >= 40 years (true positive rate= 96.30% and true negative rate=60 %), WHR>=0.87 (true positive rate= 88.9% and true negative rate=55.0%) and WC>= 85cms (true positive rate=59.3% and true negative rate=80.0%).The ROC curve for female is shown in Fig. 1.

Table-3 shows that WHR, WC, BMI and age of the male subjects covered 81.6%, 87.0%, 68.5% and 64.6% areas under ROC curve respectively with significant p-values except for the age. The risk of developing type 2 DM for male subjects increased with WC>= 87 cms (true positive rate =68.4% and true negative rate =93.3%), WHR>= 0.96 (true positive rate =57.9% and true negative rate=93.3%) and BMI>=23.63 kg/m^2 (true positive rate= 63.2% and true negative rate=73.3%.The ROC curve for male subject is shown in Fig. 2.

DISCUSSION

Obesity is a grave health problem worldwide because of its associated diseases like cardiovascular disease and type 2 DM. Various anthropometric indices which assess the degree of obesity and its associated diseases are in practice currently. However, the accuracy among these indices is still controversial. This study analyzed the association between obesity assessed by the anthropometric indices (BMI, WC and WHR) and type 2 DM by examining the predictive ability of these indices to identify the risk of type 2 DM in the population of Kavre district of Nepal.

In the present study, reference age of the diabetic females (55.30 ± 14.17 years) was found to be higher than the non-diabetics females (40.00 ± 25.24 years) and the result was highly significant. Similar trend was also observed for diabetic males (51.74 ± 23.76 years) and non-diabetic males (45.13 ± 30.94 years); however, the result was not statistically significant. These results indicate that the risk of developing diabetes is certainly higher among female subjects aged 50 and over but for the male, diabetic status may be independent with respect to the variation of age. However, the combined analysis of both male and female diabetic subjects showed that the age over 53 years might be a risk factor for both the sexes.

The reference BMI range of the diabetic females (23.07 ± 6.7 kg/m^2) was found to be lower than the non-diabetics females (23.15 ± 10.4 kg/m^2); but, the result was not statistically significant (p>0.05). The opposite trend was observed for diabetic males (24.32 ± 7.0 kg/m^2) and non-diabetic males (22.07 ± 7.4 kg/m^2) and, the result was again found not statistically significant (p>0.05). These results indicate that there was no difference in the risk

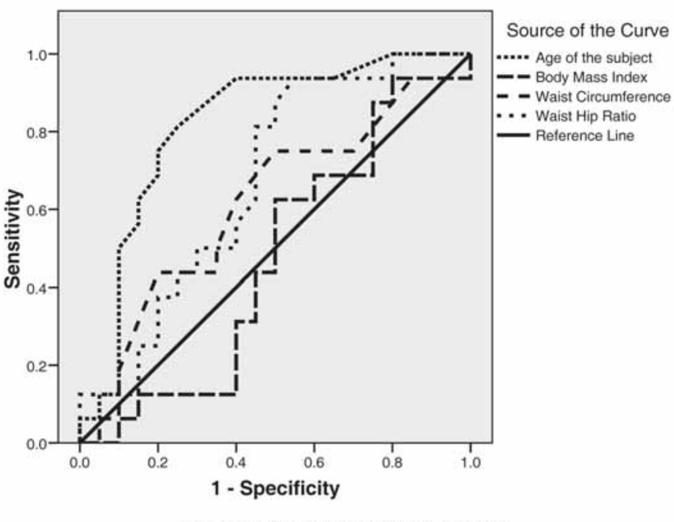

Fig. 1. ROC Curve for Female Subjects

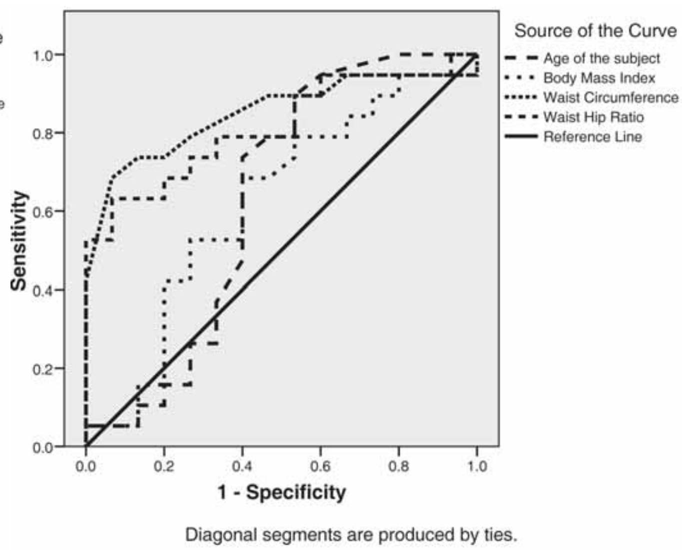

Fig. 2. ROC Curve for Male Subjects

of developing diabetics with BMI for female as well as male subjects. Even the combined analysis of both male and female diabetic subjects showed that BMI is statistically not associated with the risk of developing type 2 DM for male as well as female subjects although BMI has also been reported as being one of the most important risk factors for type 2 DM.[9] This finding was also corroborated by the study in the western region of Nepal.[10] Thus, BMI, as predictor of type 2 DM, is of less importance for the Nepalese population.

Clinical evidence suggests that the association of diabetes with central obesity is stronger that the association with general fat. Studies using computed tomography and magnetic resonance imaging have provided further evidence to support that central obesity, visceral adipose tissue, and upper body non visceral fat are the major contributors to the metabolic complications.[11-13] In the present study, reference WC of the diabetic females (82.89 ± 29.68 cms) is found to be higher than the non-diabetics females (76.95 ± 22.44 cms) but the result was not statistically significant. Similar trend was also observed for diabetic males (87.11 ± 22.30 cms) and non-diabetic males (77.53 ± 11.80 cms) and the result was highly statistically significant. These results indicate that the risk of developing diabetes is certainly higher among male subjects with waist circumference 87 cms and above but it also indicates that the female and diabetic status may be independent with respect to the variation of waist circumference. Nonetheless, it also points out by the combined analysis of both male and female diabetic subjects that waist circumference higher than 85 cms might be the risk factor for both the sexes ($p<0.001$).

We observed that reference WHR of the diabetic females (0.948 ± 0.14) is found to be higher than the non-diabetics females (0.878 ± 0.08) and the result was highly significant. Similar trend was also observed for diabetic males (1.00 ± 0.30) and non-diabetic males (0.903 ± 0.08) and the result was highly statistically significant. These results indicate that the risk of developing diabetes is certainly higher among male and female subjects with WHR more than 1.00 and 0.94 respectively. It also points out by the combined analysis of both male and female diabetic subjects that waist circumference higher than 0.98 might be the risk factor for both the sexes. Based on this analysis, we found that Waist Hip Ratio as the best predictor of the risk of developing type 2 DM among population of Kavre district of Nepal. Epidemiologic studies have demonstrated that these three obesity indicators are strong and consistent predictors of type 2 DM. In our study BMI was not found as a good predictor as comapared to WC and WHR. The reason might be the variation in the ability of these obesity indicators to predict diabetes by ethnicity, age, and sex.[14-17] For example, among Asian populations, central obesity has been shown to be more consistent predictor of diabetes than is general obesity,[18] while general obesity has been shown to be a better predictor among white US populations and Europeans.[19,20]

For female subjects, area under ROC curve, a measure of the performance of the indices in predicting diabetes,[21] was found to be highest for age followed by WHR, WC and least for BMI whereas for male subjects it was found to be highest for WC followed by WHR, BMI and least for age . It again provide the evidence that BMI might not be a good predictor for determining the risk of developing diabetes among Nepalese female population whereas age followed by WHR and WC all might be related to the diabetes in female population. In contrast, it showed that even the age might not be a good predicator for determining the risk of developing diabetes among Nepalese male population whereas WC followed by WHR and BMI all might be related to the diabetes in male population. From a statistical perspective, the two anthropometric measurements BMI and WC yield similar information with the correlation coefficient typically about 0.8.[22] Several studies have shown that WC is a better predictor of type 2 DM than BMI, but these findings are inconclusive,[23-25] while other studies provide evidence that WHR has a positive effect independent of BMI.[26] Among all the four predictors, WC and WHR are the two best predictors for type 2 DM in both male and female in the present study since BMI is found not to be associated with the risk of developing type 2 DM in female and so for age in male.

As the positive likelihood ratio[27] for age is 2.41, it indicates that age equal or above 40 years was 2.41 times likely to be found in a female with Type 2 DM than a non-diabetic female. Youden's Index and the efficiency for age equal or greater than 40 years were 0.5630 and 80.8% respectively. These values express a combined estimate of false-negative and false-positive proportions,[28] are lower but they are better than other cut-off values. Thus, we could suggest that age equal or above 40 years would pose a risk for developing Type 2 DM among Nepalese females. Nonetheless, it should be noted that our sample design allowed subjects equal or more than 30 years of age only in the study.

In female, as the positive likelihood ratio[27] for WHR is 1.98, it indicates that WHR equal or above 0.87 was 1.98 times likely to be found in a female with Type 2 DM than a non-diabetic female. In male, it is 8.68 which indicates that WHR equal or above 0.96 was 8.68 times likely to be found in a male with Type 2 DM than a non-diabetic male. Youden's Index and the efficiency for WHR equal or greater than 0.87 were 0.4389 and 74.5% respectively in female whereas in male the corresponding values for WHR equal or greater than 0.96 were 0.5122 and 67.9% respectively. These values express a combined estimate of false-negative and false-positive proportions,[28] are lower but they are better than other cut-off values. Thus, our study showed that WHR equal or above 0.87 for female and WHR equal or above for male would pose a risk for developing Type 2 DM. We observed that there was a dichotomy between the cut-off value of WHR for female and male subjects. The WHR cut-off point for female is slightly above than the one recommended by the WHO for Caucasian[29] whereas for female it is less than the value as recommended by WHO.[29] The finding of our study also endorsed that there is variation of cut-off values for different population and for the population of Kavre district may be different than as recommended by WHO.

In female, the positive likelihood ratio[27] for WC is 2.96 which indicates that WC equal or above 85 cms. was 2.96 times likely to be found in a female with Type 2 DM than a non-diabetic female. As the positive likelihood ratio[27] for male is 10.26, it indicates that for WC equal or above 87 cms. was 10.26 times likely to be found in a male with Type 2 DM than a non-diabetic male. Youden's Index and the efficiency for WC equal or greater than 85 cms. were 0.3926 and 68.1% respectively in female population whereas for male population the corresponding values for WC equal or greater than 87 cms. were 0.6175 and 75.5% respectively. These values express a combined estimate of false-negative and false-positive proportions,[28] are lower but they are better than other cut-off values. Thus, this study found that WC equal or above 85 cms in female and WC equal or above 87 cms in male population would pose a risk for developing Type 2 DM. The cutoff point in female is surprisingly high than the value suggested for asian female population[30] (WC>= 80). This result might be because of WC being the ethnic specificity. In Kavre district the newari ethnic group is more and the newari female may have higher WC as shown by our study. To facilitate use of WC both in the clinical practice and in health promotion programs the following cut-off points were described as action levels: at action level 1 (WC >= 80cm for women and WC>= 94 for men), the individual has a higher risk of morbidities associated with obesity and should be advised to stop gaining weight and to adopt a healthy life style and at level 2 (>= 88cm for women and WC>= 102cm for men): The individual has a very increased risk of morbidities associated with obesity and should seek urgent help from a health professional to lose weight and be assessed for other risk factor.[31] The WC cutoff levels for female found in this study were higher than the value at action level 1 which is similar to the finding in the study carried out in the Mexican population[32] but in contrast to the finding in the study in the Asian Indian Adults.[33] The showed that WC cut-off levels for Asians not only vary from the casucasian population but also different Asian population differ in the level of risk associated with a particular WC. In contrast to female, the WC cut-off value in male in our study is less than as mentioned in action level 1 (WC>=94 cms). This is also similar to the finding of the study in Asian Indian Adults[33] (WC> = 85 cms). We observed that adults of Nepalese population have higher type 2 DM risk factors at lower WC than western populations. Lower WC in adults of asian origin has also been also reported to have higher cardiovascular risk factors.[34] It is beneficial to healthcare to assess what values of WC measurements are associated with the presence of chronic conditions such as diabetes, hypertension, or dsyslipidemia in different populations.

As the positive likelihood ratio[27] is 2.37, it indicates that for BMI equal or above 23.63 was 2.37 times likely to be found in a male with Type 2 DM than a non-diabetic male. Youden's Index and the efficiency for BMI equal or greater than 23.63 were 0.3649 and 66.0% respectively. These values express a combined estimate of false-negative and false-positive proportions,[28] are low but they are better than other cut-off values. Thus, we can suggest that BMI equal or above 23.63 kg/m^2 would pose a risk for developing Type 2 DM among Nepalese males.

The current study showed that the WC and WHR are the best predictor of type 2 DM in both male and female population of Kavre district. The cut-offs values of the anthropometric indices should be reassessed to predict the diseases associated with them.

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