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Original Article

Appropriate body mass index cut-off point in relation to type 2 diabetes mellitus in the population of Kavre district

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Abstract

Objective: The objective of the present study was to find out the appropriate BMI cut-off point in relation to type 2 Diabetes Mellitus (DM) in the population of Kavre district of Nepal.

Materials and methods: Thirty-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 and weight were recorded for every subject. BMI was calculated by the standard formula. The data was analyzed using SPSS Version 11.5.

Results: Our results showed that the reference BMI range for both diabetic male (23.26 ± 6.88 kg/m^2) and diabetic female (22.51 ± 6.28 kg/m^2) subjects were within normal BMI range according to WHO. Odds ratio showed an irregular pattern at different BMI ranges indicating the risk of having diabetes did not increase constantly. Comparison of number and percentage of both diabetic and non-diabetic male and female subjects according to various recommended normal BMI categories showed gradual reduction in percentage of both diabetic and non-diabetic male and female subjects that were within normal ranges from BMI category 18.5-24.9 kg/m^2 to BMI category 18.5-21.9 kg/m^2 .The BMI cut-off point was found 22 kg/m^2 using Receiver Operating Characteristic (ROC) curves.

Conclusion: The appropriate BMI cut-off point for both men and women was found 22 kg/m^2 in the population of Kavre district of Nepal.

Key words: BMI cut-off points, Type 2 DM, Kavre district

Diabetes Mellitus (DM) is a syndrome of impaired carbohydrate, fat and protein metabolism caused by either lack of insulin secretion (Type 1) or decreased sensitivity of tissue to insulin (Type 2)[1]. Risk factors for type 2 DM are Body Mass Index (BMI), Waist Circumference (WC), Waist Hip Ratio (WHR), hypertension, sex, ethnicity, sedentary life style, family history and smoking. Among them, BMI is observed as one of the major risk factor for type 2 DM.

BMI is an anthropometric measurement which is considered as an index of obesity. It is the most frequently used indicator of total body adiposity in epidemiological studies[2]. At present, the World Health Organization (WHO) recommends a BMI range of 18.5-24.9 Kg/m^2 as the criteria for normal weight and 25-29.9 Kg/m^2 as overweight, which was largely derived from mortality statistics from European and American populations[3]. In contrary to this, in Asian subjects when compared with white population, the risk association with diabetes and cardiovascular diseases occur at lower levels of BMI[4]. This has been attributed to differential body fat distribution. Asian Indian tends to have more visceral adipose tissue, causing higher insulin resistance despite having lean BMI[5]. Several studies carried out among Asian population have challenged the notion that one BMI cut-off point fits all population. Epidemiological studies have also shown that the ideal BMI may differ in different countries.

Recently in 2002, WHO experts addressed and debated about BMI cut-off point for determining overweight and obesity in Asian populations. They noted that the number of Asians with a high risk of type 2 DM and cardiovascular diseases were found to have BMIs lower than 25 Kg/m^2 [6].

In several studies, the BMI cut-off point for overweight in different Asian countries found, are- 22 Kg/m^2 in Japan[7], 23 Kg/m^2 in India[8] and 24 Kg/m^2 in China[9]. Therefore it has been suggested that lower BMI cut-off

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points for overweight and obesity appropriate for Asian population should be adopted. So, the aim of the present study is to find out the appropriate BMI cut-off point in relation to type 2 DM in the population of Kavre district of Nepal.

Material and methods

***Selection of subjects*:** Thirty-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[10]:

- 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 were measured following the standard procedure.

Measurement of height

Height was measured by using a calibrated standiometer. The subject stood bare foot, and erect with heels together and arms hanging naturally by the sides. The heels, buttocks, and upper parts of back, the back of the head were in contact with the vertical wall. The subject looked straight ahead and took a deep breath during measurement. The distance from the platform of the standiometer to the highest position of the head (vertex) was measured with the help of standiometer reading, which indicated subjects' height. The height was recorded to the nearest centimeter.

Measurement of weight

Body weight was taken by calibrated portable weighing machine. During the measurement of weight, the subject was standing with their weight evenly balanced on both feet and the distance between the feet about 30 cm apart. During weight measurement, subject wearing minimum clothes (as is culturally appropriate for the setting) stood at the center of weighing machine looking straight. The weight was recorded nearest to kilograms.

Calculation of BMI

From height and weight taken from an individual subject BMI was calculated by following formula:

BMI= Weight in kilograms / Square of height in meters (kg/m^2)

Statistical analysis

Data entry and analysis were done using Statistical Package for Social Sciences (SPSS) Version 11.5. At first, odds ratios[11] were calculated for the various BMI values[8] and diabetic status (Diabetics/Non-diabetics) using binary logistic regression[12] in order to determine the BMI cut-off point associated with the detection of diabetes in the study population. Later, arithmetic mean, confidence interval of the mean, standard deviation, minimum and maximum values for selected variables were computed for diabetic and non-diabetic subjects. Gender disaggregated one-way analysis of variance (ANOVA) was performed for these selected variables. Fisher's F-Ratio test and its associated p-values were used to confirm the statistical validity of the results obtained from ANOVA. BMI cut-off points for various normal ranges were obtained using different BMI categories. The results were then analyzed and compared in terms of their relative frequency to identify the most plausible BMI cut-off point related to the occurrence of diabetes. Later, Receiver Operating Characteristic (ROC) curves were used to find and confirm the cut-off point of BMI associated with the risk of developing diabetes for male as well as female subjects.

Results

The descriptive statistics for age and BMI of the subjects by gender and controlled by diabetic status are presented in Table 1.

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. After controlling for diabetic status, reference age of the diabetic male and female subjects was found to be 50.26 ± 12.31 years and 53.36 ± 26.04 years respectively. Similarly, reference age of the non-diabetic male and female subjects was found to be 45.13 ± 30.94 years and 40.00 ± 25.24 years respectively.

After controlling for diabetic status, reference BMI of the diabetic and non-diabetic male subjects was found to be 23.26 ± 6.88 kg/m^2 and 22.07 ± 7.40 kg/m^2 respectively whereas the reference BMI of diabetic and non-diabetic female subjects was found to be 22.51 ± 6.28 kg/m^2 and 23.15 ± 5.21 kg/m^2 respectively.

The odds ratios of diabetes for different BMI ranges among male and female subjects are shown in fig 1.1 and 1.2. For male and female subjects, the risk of having diabetes did not increase constantly.

Figure 1.1 revealed that the risk of having diabetes was 20 % higher for BMI range of 20-21 kg/m^2 and 23-24 kg/m^2 among male subjects. Similarly, figure 1.2 showed the risk of diabetic being detected was 60 % higher for BMI range 20-21 kg/m^2 and > 25 kg/m^2 among female subjects.

Classification of overweight was done in all subjects according to WHO criteria[3] and as per the recommended normal BMI cut- off point found in various Asian countries like Japan[7] (normal BMI cut-off < 22 kg/m^2), India[8] (normal BMI cut-off < 23 kg/m^2) and China[9] (normal BMI cut-off < 24 kg/m^2). Comparison of the percentage of both diabetic and non-diabetic male and female subjects done in various normal BMI categories are presented in Table 2.

The percentage of both diabetic and non-diabetic subjects, that were within normal BMI ranges, were gradually decreased from BMI category 18.5-24.9 kg/m^2 to BMI category 18.5-21.9 kg/m^2 and majority of subjects were found within normal BMI ranges of 18.5-24.9 kg/m^2 to 18.5-22.9 kg/m^2. In the BMI category 18.5-21.9 kg/m^2, it decreased below 18%. However, the percentage of diabetic female subjects within normal BMI ranges were not decreased too much till BMI category 18.5-22.9 Kg/m^2. But the percentage was decreased to half in BMI category 18.5-21.9 kg/m^2. Surprisingly, the percentage of diabetic and non-diabetic female subjects was found equal in the BMI category 18.9-21.9 kg/m^2.

The ROC curves for BMI for male and female subjects are shown in Fig 2.1 and Fig 2.2. The result from ROC curve for different BMI cut-off points is presented in Table 3. The overall area under curve for male subjects (0.619) and female subjects (0.469) represented the probability that the BMI result for a randomly chosen diabetic case would exceed the result for a randomly chosen non-diabetic case. This means that probability of detecting diabetic case against non-diabetic case was greater among male than the female subjects. These results were not statistically significant.

Table 3 shows the true positive and false positive rates for male and female subjects separately. The true positive rate shows the probability of detecting true diabetics whereas the false positive rate shows the probability of detecting false diabetics at that particular BMI cut-off point. In BMI cut-off point 22 kg/m^2, we found the optimum value of true positive rate 0.684 for male and 0.625 for female at the lowest possible value of false positive rate 0.467 for male and 0.500 for female.

Based on these facts, it was found that BMI of 22 kg/m^2 is the cut-off point for detecting diabetes for both male and female subjects among the study population.

Table 1: Descriptive Statistics of Age and BMI by Gender and Diabetic Status

Gender	Diabetic status	Mean		Std. Deviation	
		Age of the subject (years)*	Body Mass Index**	Age of the subject (years)*	Body Mass Index**
Male	Diabetic	50.26	23.26	12.32	3.44
	Non-diabetic	45.13	22.07	15.47	3.71
	Total	48.00	22.73	13.82	3.55
Female	Diabetic	53.38	22.21	13.02	3.16
	Non-diabetic	40.00	23.15	12.62	5.21
	Total	45.94	22.73	14.30	4.38
Total	Diabetic	51.69	22.78	12.56	3.30
	Non-diabetic	42.20	22.69	13.94	4.59
	Total	46.94	22.73	14.01	3.97

*Fisher's F Ratio Test = 0.373 with p-value > 0.05 (0.543)
**Fisher's F Ratio Test = 0.000 with p-value > 0.05 (0.995)

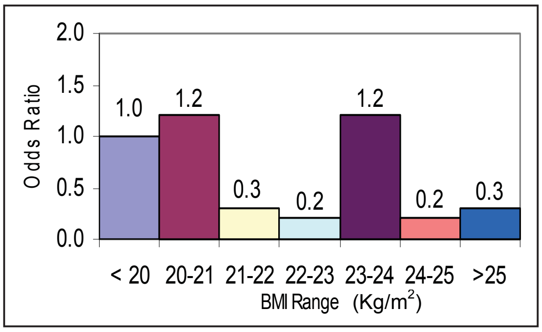

Fig 1.1: Male Subjects

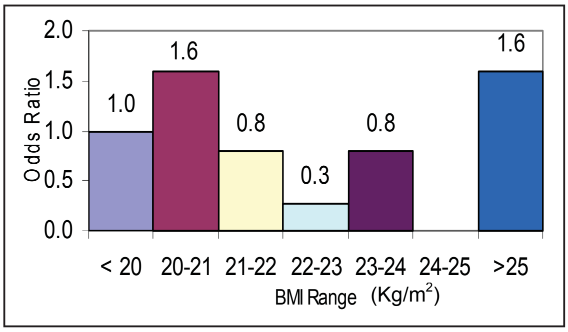

Fig 1.2: Female Subjects

Table 2: Comparison of the number and percentage of both diabetic and non-diabetic male and female subjects according to various recommended normal BMI categories

Normal BMI categories (kg/m^2)	Male (n=34)				Female (n=36)			
	Diabetic		Non-diabetic		Diabetic		Non-diabetic	
	n	%	n	%	n	%	n	%
18.5-24.9[a]	12	35.29	10	29.41	13	36.11	12	33.33
18.5-23.9[b]	9	26.47	9	26.47	13	36.11	9	25.00
18.5-22.9[c]	8	23.52	7	20.58	12	33.33	8	22.22
18.5-21.9[d]	5	14.70	6	17.64	6	16.66	6	16.66

Note: Recommended normal BMI Category in: a= WHO, b= China, c= India & d = Japan. n= number of subjects, %= percentage

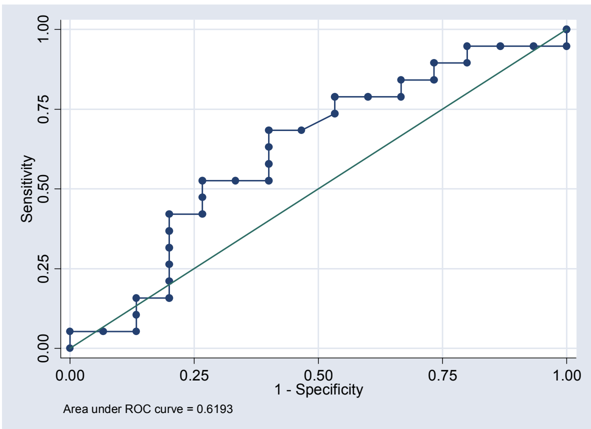

Fig 2.1: ROC Curve for Male Subjects

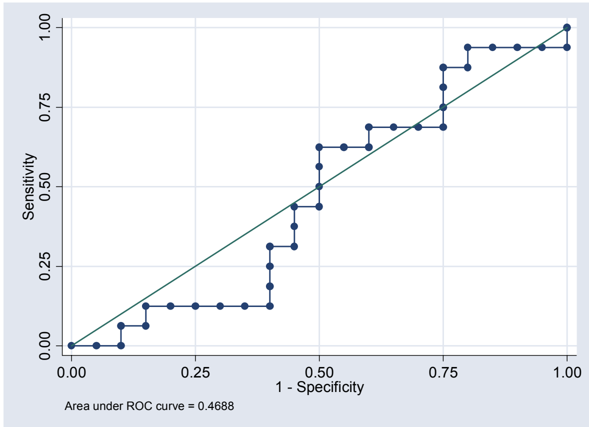

Fig 2.2: ROC Curve for Female Subjects

Table 3: BMI cut-off values with the probability of diagnosing as diabetics

BMI Cut-off Point (kg/m^2)	Male[a]		Female[b]	
	True Positive Rate	False Positive Rate	True Positive Rate	False Positive Rate
>= 20	0.842	0.667	0.813	0.750
>= 21	0.789	0.533	0.625	0.550
> = 22	***0.684***	***0.467***	***0.625***	***0.500***
>= 23	0.526	0.400	0.250	0.400
>= 24	0.474	0.267	0.125	0.350
>= 25	0.316	0.200	0.125	0.200

a. The overall curve area for males is 0.619 with standard error of 0.101 and p-value > 0.05.
b. The overall curve area for females is 0.469 with standard error of 0.098 and p-value > 0.05.

Discussion

Asian Indians have an increased susceptibility to Type 2 DM and insulin resistance as compared to Europeans[13]. Insulin resistance and prevalence of diabetes is rising in India[14] and Nepal[15] which is due to major contributing factor obesity. However, Asian Indians are known to have lower BMIs than Europeans[16]. Several studies in Asian countries have also shown the low BMI cut-off point than the one recommended by WHO[3].

In the present study, we observed that the reference age of the diabetic male and female subjects were higher than the non-diabetic male and female subjects indicating that the risk of developing diabetes is higher for males and females of age 50 and above. This however was found to be statistically not significant.

In the present study regarding the reference BMI range, a dichotomy was found between male and female subjects. The reference BMI range of the diabetic male subjects was found to be higher than the non-diabetic male subjects whereas BMI range of diabetic female subjects was found to be lower than the non-diabetic female subjects. These results indicated that BMI was not affected even after controlling for the diabetic status. The results were not statistically significant (p-value > 0.05). So, Asians are probably more prone to develop diabetes because of other risk factors.

However, mean value of BMI for both diabetic male and diabetic female subjects were found to be within the normal BMI range as recommended by WHO[3] which provided the primary evidence to the fact that the BMI cut-off point in the population of Kavre district should be lowered. Furthermore, the mean value of BMI, in both diabetic male and female subjects was found lower than that reported in the study in the population of western region of Nepal[17]. This difference in BMI value might be due to the various factors like geographical variations, life style, occupational status, genetic factor or ethnic differences of the population. Kavre being the hilly region, transportation facility is very less and also people have to walk up and down to do their daily jobs. This provides them the sufficient physical exercise. In addition, it is a rural area and people are relatively poorer who might consume low calorie and fat diet. Thus, their physically active life and dietary factors seem to be more responsible for the comparatively lower BMI in both diabetic male and female subjects.

The odds ratios of having diabetes for different BMI among total male and female subjects were examined in the present study (figure 1.1 and 1.2.) For male and female subjects, the risk of having diabetes was not increased constantly as found by other studies[8, 14]. The present study showed lopsided trend of odds ratio at different BMI ranges and most strikingly the odds ratios for different BMI ranges were found to be statistically not significant (p-value > 0.05) which was the main basis of defining cut-off point of BMI and probability of detecting diabetes[8]. In contrast, one of the studies in Asian Indian Adults[8] have observed that, for both men and women, the association was significant in the BMI categories of > 23-24 kg/m^2 (P=0.0045, OR 2.27, 95% CI 1.29-3.99 for men; P=0.009, OR 2.03, 95% CI 1.19-3.46 for women). This might have happened due to the small number of samples in the present study (70 subjects) rather than the large sample size (10,025 subjects[8]). Therefore a large study subjects should be taken to identify the BMI cut-off point which is the limitation of our study.

When both diabetic and non-diabetic male and female subjects were compared according to various normal BMI categories suggested by various Asian countries[7,8,9], gradual reduction in the percentage of the diabetic male and female subjects from the BMI category 18.5- 24.9 kg/m^2 to 18.5-21.9 kg/m^2 was found. The minimum percentage in diabetic male & female subjects was observed in BMI category 18.5- 21.9 kg/m^2. This showed that when normal BMI category was considered according to WHO[3] higher percentage of both diabetic male (35.29%) and female (36.11%) subjects were within normal ranges. When normal BMI cut-off point was considered as 22 kg/m^2, 14.70% diabetic male and 16.66% diabetic female were found within normal range which was found to be much less than the percentage of diabetic male and female subjects found within normal range when normal BMI cut-off point was considered as per WHO[3]. So this result also suggested that the appropriate BMI cut-off point was around 22 kg/m^2. Similarly, In BMI category 18.5-21.9 kg/m^2, percentage of diabetic male within the normal range was found less than non-diabetic male which also provided the evidence for the BMI cut-off point 22 kg/m^2. This observation was also in accord with other studies from northern parts of India which had shown that the normal BMI for an Indian was < 22 kg/m^2 [18]. The relationship of diabetes and impaired glucose tolerance for BMI value of >22 kg/m^2 had also been established in Asian countries.

The normal BMI cut-off points as per WHO[3] classification have been questioned by several studies in Asian countries. It has been shown that the BMI cut-off points for the prescribed classification as overweight and obese differed from those recommended by WHO. For some Asian populations, including those from Taiwan[19], Hongkong[20], and Singapore[21], the corresponding BMI cut-off points for overweight and obese were 23 kg/m^2 and 25-27 kg/m^2 respectively. In the present study, Receiver Operating Characteristic (ROC) curve was used to find the cut-off point of a quantitative variable of interest (such as BMI) for a particular attribute of an outcome variable (being diabetic within the diabetic status) [22]. The ROC curve was drawn under parametric conditions as the variable of interest followed the normal distribution, which was assessed using normality tests such as Kolmogorov-Smirnov (K-S) and Shaphiro-Wilk (S-W) test. In the present study, the K-S test and S-W test for male BMI were found to be normal (p-value > 0.05) whereas the same tests for female BMI were not found following the normal distribution (p-value < 0.01). As the condition of normality was violated, the ROC curve was drawn under non-parametric conditions which holds good for values following normal distribution and there is no assumption made about the parametric distribution for a quantitative variable. Thus, ROC curve for both male and female subjects were obtained under non-parametric conditions in order to compare and then validate their findings.

The ROC curve analysis of the data showed that the BMI cut-off point for both male and female subjects was 22 kg/m^2. At BMI cut-off point 22 kg/m^2, we found that the true positive rate was greater than 50% and false positive rate was less than 50%. Hence, the probability of detecting true diabetes is optimum with the lowest possible value of false positive rate. This BMI cut-off point is much less than the normal BMI cut-off point recommended by WHO[3].

Conclusion

The appropriate BMI cut-off point for both men and women was found 22 kg/m^2 in the population of Kavre district of Nepal. Since this is a small scale study, further extensive study nationwide is required so that the appropriate BMI cut-off point could be derived for the national level for planning of programs to prevent obesity and obesity-related diseases like diabetes and cardiovascular diseases.

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