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# Lifestyle, BMI, Age and Waist-to-Height Ratio as Indicators for Type 2 Diabetes Mellitus: A Gender Based Comparative Study in Kolkata, West Bengal, India

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**ABSTRACT**
The study aimed to investigate whether there is a differential impact of age, lifestyle, BMI, and waist-to-height ratio on the risk of Type 2 diabetes mellitus in males and females in a cross-sectional study in Kolkata, West Bengal, India. A sample of size 428 was observed from the outpatient consultation department of Belle Vue Clinic in Kolkata. Interrelationships between the measures were explored using correlation heat maps. The predictive powers of models based on age, BMI, and lifestyle were compared to those based on age, waist-to-height ratio, and lifestyle using receiver operating characteristic curves based on logistic regression models, separately for males and females. The risk of diabetes was found to increase significantly with age in both males and females. Although exercise and BMI were found to have a significant impact on the risk of Type 2 diabetes in males, in females both turned out to be statistically insignificant. In both males and females, predictive models based on waist-to-height ratio were found to perform better than those based on BMI.

**KEYWORDS**
Type2 Diabetes Mellitus; BMI; Waist to height ratio (Whtr); Multicollinearity; Logistic Regression.

## 1. Introduction

Diabetes is a rapidly growing non-communicable disease, which is becoming a significant health challenge for developing countries like India. Type 2 diabetes mellitus, the most common form of diabetes, is caused by a varying combination of insulin resistance disorder and/or insufficient insulin secretion. India ranks second globally for the number of adults with diabetes, with more than 74 million people diagnosed in 2021. Estimates project that by 2045, 124.9 million people in India will have diabetes [1].

Although excess body weight, obesity, and a sedentary lifestyle have been identified as the major risk factors of Type 2 diabetes, not all the risk factors for type 2 diabetes are completely known. In predicting the risk of Type 2 Diabetes Mellitus, anthropometric measures like waist circumference (WC), waist-to-height ratio (Whtr), body fat

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percentage, and body mass index (BMI) have already been used in different studies [2-4]. Although BMI can be easily measured, it fails to discern between body fat and lean body mass and hence fails to provide information on body fat distribution. Another commonly used measure, waist circumference, does not reflect the variation in lean mass, body shape, and height in different ethnic groups [5]. Some studies have shown that Whtr, being a measure of central obesity, outperforms other anthropometric measures like BMI and waist circumference in predicting cardiometabolic abnormalities [6].

Studies from all over the world have shown that the performance of different anthropometric measures in predicting the risk of Type 2 Diabetes Mellitus varies among different subpopulations. Hence, it is necessary to study the predictive powers of the anthropometric measures separately for different ethnic or geographical groups. Research has indicated that the prevalence of diabetes differs between obese men and women [7]. Age has also been identified as a high-risk factor for Type 2 diabetes in various studies [8].

The principal objective of this study is to establish and compare the predictive powers of BMI and waist-to-height ratio, along with age and lifestyle factors, for predicting the risk of diabetes separately in males and females in Kolkata, West Bengal, India. Additionally, we intend to examine the interdependence among different predictors such as age, height, weight, waist circumference, body mass index (BMI), and waist-to-height ratio through correlation heat maps.

## 2. Methods

A cross-sectional study was conducted on 428 patients seeking treatment at the outpatient consultation department of Belle Vue Clinic from March to May 2022. Out of the 428 patients aged 20 years or older considered for the study, 211 were diagnosed with Type 2 diabetes mellitus, and 217 tested negative. Following the guidelines of the hospital's Ethics Committee, participants were informed about the study's purpose before data collection.

Subjects were tested for diabetes by measuring fasting plasma glucose by the Hexokinase method. Fasting Blood Glucose was checked after fasting overnight. Cut off of $\geq 126$ mg/dl was taken as Diabetic in the fasting state. 2 hour Post Prandial blood glucose of $\geq 200$ mg/dl and/or HbA1c of $\geq 6.5$ (measured by HPLC method) or above were taken as Diabetic.

Height was measured twice, and the average was calculated using a wall-mounted measuring scale while the subject stood upright and looked forward. Weight was measured twice, and the average was determined with the subject standing upright and looking straight using a digital weighing machine.

Waist circumference was checked twice and the average was taken using a flexible measuring tape with the subject standing and looking forward. The measurements were taken at the midpoint of the Iliac crest anteriorly and the lower ribs.

Information on Lifestyle activity and Gender was supplied by the respondents themselves. BMI and waist-to-height ratio (henceforth referred to as Whtr) was derived from the variables described in Table1.

Different studies have indicated an increased risk of diabetes with an increase in age [8]. According to the National Institute of Diabetes and Digestive and Kidney Diseases, the risk of diabetes increases significantly if the age is $\geq 45$ years.

Many studies have suggested a differential risk of diabetes in males and females

[9, 10]. Hence, the data were analyzed by gender to understand how lifestyle and anthropometric measurements assist in assessing diabetes in males and females with age.

Accordingly, we have stratified the data by age and gender [Table 1]. Correlation heat maps were utilized to examine the interrelationships among different anthropometric variables. Predictive models were developed, taking into consideration the nature of interdependence between the predictors as revealed by the heat maps. Statistical analysis was conducted using R software.

**Table 1.** showing gender wise and age wise stratification of the data

| Age | Male | Female | Total |
|---|---|---|---|
| $< 45$ | 61 | 63 | 124 |
| $>= 45$ | 143 | 161 | 304 |
| *Total* | 204 | 224 | 428 |

**Table 2.** Description of the variables under study.

| Predictors | Type | Observed Range/ Categories |
|---|---|---|
| *Age* | Continuous | Min: 20, Max: 88 |
| *Sex* | Categorical | 204 Males and 217 Females |
| *Height* | Continuous | Min:139 cm, Max: 189.5 cm |
| *Weight* | Continuous | Min: 41.8 kg, Max:144.4 kg |
| *WaistCircumference(cm)* | Continuous | Min=64; Max=143 |
| *Lifestyle* | Categorical | 4 categories: Does not exercise<br>Somewhat exercises<br>Moderately exercises<br>Exercises daily |

### 2.1. Statistical Methods

Correlation between the variables described in Table 2 was studied using correlation heat maps and pairwise scatter plots. Multiple binary logistic regression was used to model the risk of Type 2 diabetes mellitus separately in males and females. The performance of the predictive models was compared between males and females using receiver operating characteristic (ROC) analysis. The area under the curve (AUC) and Akaike information criterion (AIC) were also considered to compare the accuracy of the fitted models.

## 3. Results

The average age of the participants was 53.32 years, with a standard deviation of 14.72 years. The mean height of the participants was 162.1 cm, with a standard deviation of 9.62 cm. The average weight of the participants was 72.63 kg, with a standard deviation of 15.38 kg.

The correlation heat map in Figure 1 shows a high correlation ($r = 0.8$) between BMI and Whtr. Due to the high level of multicollinearity between BMI and Whtr, separate predictive models were developed based on age, lifestyle, BMI, and age, lifestyle, and Whtr for males and females.

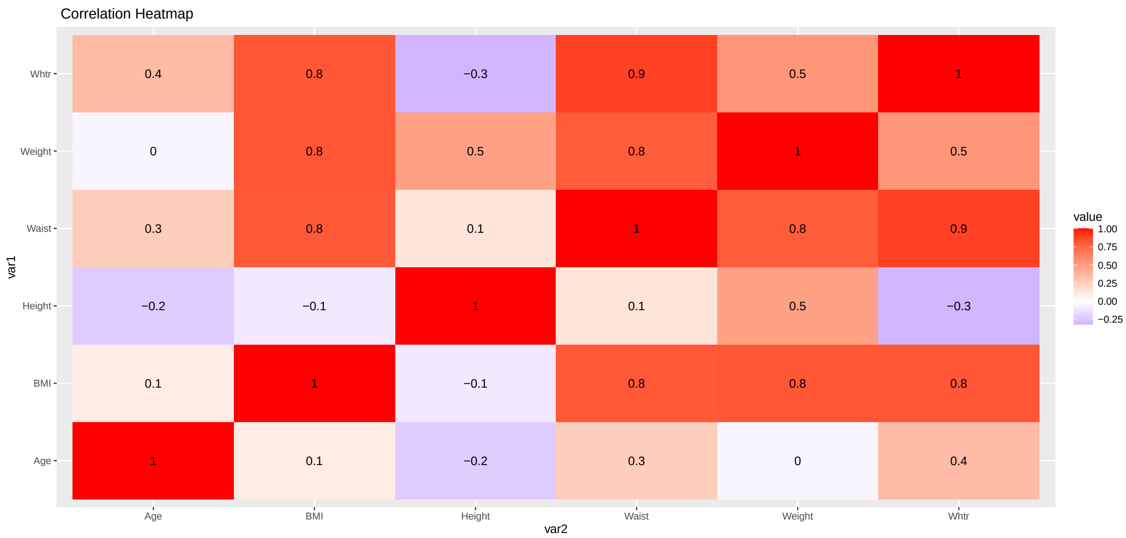


**Figure 1.** Correlation heat map depicting the correlations between Age, BMI, Height, Weight, Waist circumference, and Waist to height ratio.

The pairwise scatter plot in Figure 2 sheds light on the correlation patterns between age and weight, age and BMI, height and BMI, and height and waist in males and females. For fixed levels of height or weight, on average, females tend to have a higher BMI than males. For fixed levels of weight, on average, females tend to have a higher waist-to-height ratio (Whtr).

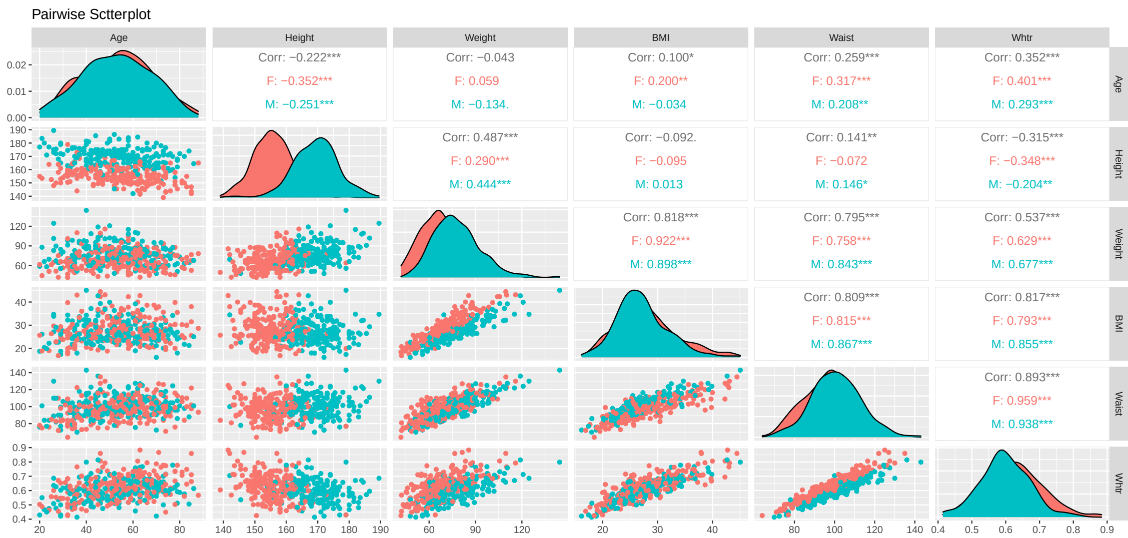


**Figure 2.** Pairwise scatter plot for Age, Height, Weight, BMI, Waist circumference, and Waist to height ratio.

Next, we fitted multiple binary logistic regression models separately for males and females. Due to strong existing evidence supporting an increased risk of Type 2 diabetes mellitus beyond the age of 45 years in the Indian population [8], the variable 'age' has been categorized as $< 45$ years and $\geq 45$ years.

Table 3 summarises the results for the fitted predictive models based on Age, BMI, and lifestyle for males and females. Age turns out to be a highly significant factor (p-value ≈ 0) for both males and females. Lifestyle is a significant factor for males only (p-value: Somewhat Exercises-0.074, Moderately Exercises-0.0003, and Exercises Daily-0.022); however, it is not a significant factor for females. BMI is a significant factor for males (p-value- 0.032) only. Surprisingly, BMI turns out to be an insignificant factor for females (p-value- 0.553). BMI has been identified as a high-risk factor for Type 2 diabetes mellitus in different studies [10,11,12]; hence, further investigation is needed.

**Table 3.** Summary of the fitted predictive model of Diabetes for Males and Females, based on Age, BMI, and Lifestyle.

| Predictors | Variable Name | Estimates | | P value | | AUC | | AIC | |
|---|---|---|---|---|---|---|---|---|---|
| | | Females | Males | Females | Males | Females | Males | Females | Males |
| Intercept | Intercept | -1.928 | -3.559 | 0.017 | 0.002 | | | | |
| Age | Age(≥ 45) | 2.069 | 2.729 | ≈ 0 | ≈ 0 | | | | |
| BMI | BMI | 0.017 | 0.082 | 0.553 | 0.032 | 0.701 | 0.801 | 278.89 | 233.99 |
| Lifestyle | Somewhat exercises | -0.03 | -0.793 | 0.939 | 0.074 | | | | |
| | Moderately exercises | -0.594 | -1.542 | 0.189 | 0.003 | | | | |
| | Exercises Daily | -0.187 | -1.052 | 0.642 | 0.022 | | | | |

The area under the ROC curve in Figure 3 shows that BMI, along with age and lifestyle, has good accuracy in predicting the risk of Type 2 diabetes mellitus for males (AUC = 0.801). Among females, it has fair accuracy in predicting the risk of Type 2 diabetes mellitus (AUC = 0.701).

Thus, we can observe that Age+BMI+Lifestyle performs better in predicting the risk of type 2 diabetes mellitus for males than for females. The AIC value for males (AIC = 233.99) is less than the AIC value for females (AIC = 278.9), which again supports the fact that BMI along with Age and Lifestyle performs better for males than for females in predicting the risk of type 2 diabetes. See Figure 3 for a diagrammatic summary of the comparison of different predictive models using ROC curves.

**Table 4.** Summary of the fitted predictive model of Diabetes for Males and Females, based on Age, Waist-to-height ratio (Whtr), and Lifestyle.

| Predictors | Variable Name | Estimates | | P value | | AUC | | AIC | |
|---|---|---|---|---|---|---|---|---|---|
| | | Females | Males | Females | Males | Females | Males | Females | Males |
| Intercept | Intercept | -4.582 | -5.667 | ≈ 0 | ≈ 0 | | | | |
| Age | Age(≥ 45) | 1.809 | 2.484 | ≈ 0 | ≈ 0 | | | | |
| Waist to height ratio | Whtr | 5.222 | 7.531 | 0.01 | 0.038 | 0.746 | 0.806 | 272.16 | 229.88 |
| Lifestyle | Somewhat exercises | -0.104 | -0.839 | 0.795 | 0.063 | | | | |
| | Moderately exercises | -0.426 | -1.526 | 0.359 | 0.004 | | | | |
| | Exercises Daily | -0.041 | -0.979 | 0.921 | 0.033 | | | | |

Table 4 summarises the results for the fitted predictive models based on Age, Waist to height ratio, and lifestyle for males and females. Age turns out to be a highly significant factor (p value ≈ 0) for both males and females. Lifestyle is a significant factor for males only (p value: Somewhat Exercises-0.063, Moderately Exercises-0.004, and Exercises Daily-0.033). Waist to height ratio turns out to be a significant factor for both males (p value- 0.038) and females (p value- 0.01).

The area under the ROC curve shows that Whtr, along with Age and Lifestyle, has good accuracy in predicting the risk of Type 2 diabetes mellitus for males (AUC = 0.806). Among females, it has fair accuracy in predicting the risk of Type 2 diabetes mellitus (AUC = 0.746). Thus, we can observe that Whtr+Age+Lifestyle performs better in predicting the risk of Type 2 diabetes mellitus for males than for females. The AIC value for males (AIC = 229.88) is less than the AIC value for females (AIC = 272.16), which again supports the fact that Whtr, along with Age and Lifestyle, performs better for males than for females in predicting the risk of Type 2 diabetes.

From the AUC and AIC values, we also see that Age+Whtr+Lifestyle performs better than Age+BMI+Lifestyle for both males and females in predicting the risk of Type 2 diabetes mellitus. Figure 3 summarises the performance of various predictive models based on ROC curves.

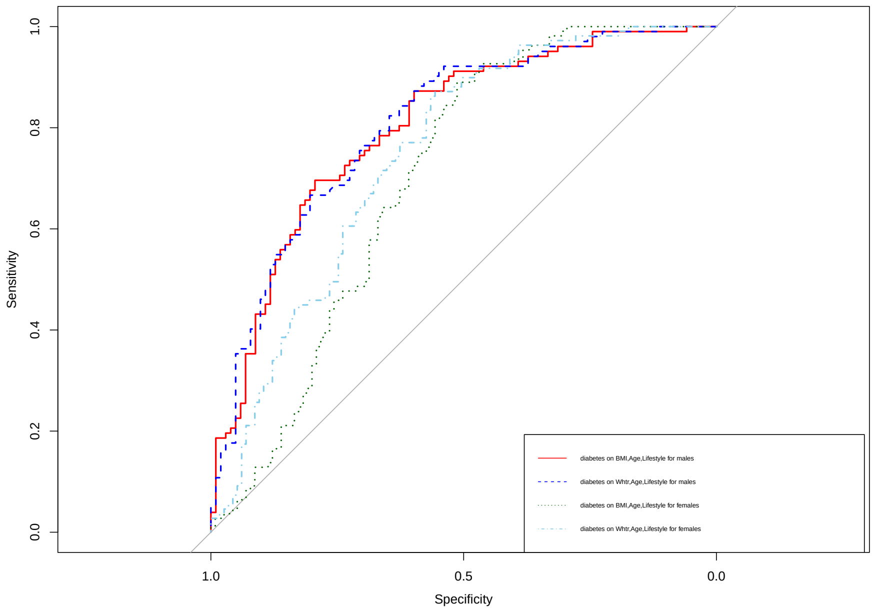


**Figure 3.** ROC curves comparing the predictive models based on BMI+Age+Lifestyle for males, Whtr+Age+Lifestyle for males, BMI+Age+Lifestyle for females and Whtr+Age+Lifestyle for females.

We also note that the estimated odds of Type 2 diabetes mellitus increase multiplicatively by 1.085 for a one-unit increase in BMI in males, controlling for other variables, i.e., there is an 8.5% increase. However, the estimated odds of Type 2 diabetes mellitus increase multiplicatively by 1864.99 for a one-unit increase in Whtr in males, controlling for other variables. For females, we observe that the estimated odds increase multiplicatively by 185.3044 for a one-unit increase in Whtr, controlling for other variables.

We also note that, controlling for BMI and Lifestyle, the estimated odds of Type 2 diabetes mellitus for a male aged $\geq 45$ is 15.318 times the estimated odds for a male aged $<45$. For a female aged $\geq 45$, the estimated odds of Type 2 diabetes mellitus are 7.917 times the estimated odds for a female aged $<45$.

We observe that, controlling for Whtr and Lifestyle, the estimated odds of Type 2 diabetes mellitus for a male with Age $\geq 45$ is 11.989 times the estimated odds for a male with age $<45$. For a female with Age $\geq 45$, the estimated odds of Type 2 diabetes mellitus are 6.104 times the estimated odds for a female with age $<45$.

In the case of Lifestyle, we see that controlling for Age and BMI, the estimated odds of Type 2 diabetes mellitus in males who Somewhat Exercises, Moderately Exercises, and Exercises Daily are respectively 0.452 times, 0.214 times, and 0.349 times the odds for males who do not exercise.

In the case of Lifestyle, we see that controlling for Age and Whtr, the estimated odds of Type 2 diabetes mellitus in males who Somewhat Exercises, Moderately Exercises, and Exercises Daily are respectively 0.432 times, 0.2174 times, and 0.376 times the odds for males who do not exercise.

## 4. Discussion and Conclusions

One very important observation in our study is that BMI turns out to be insignificant for females in predicting the risk of diabetes mellitus. This contradicts previous findings from different studies [2-4]. To investigate further, the Mann-Whitney U test was performed, yielding a p-value as high as 1, indicating that the medians of the BMIs are not significantly different for the female cases and controls under observation.

From our study, we observe that waist-to-height ratio and age greater than or equal to 45 years are two high-risk factors for Type 2 diabetes mellitus among both males and females in Kolkata. Hence, beyond the age of 45, more care should be taken to prevent Type 2 diabetes in both males and females. Although exercising was found to have a negative association with the risk of diabetes in males, it turned out to be insignificant in females. This unexpected result demands further study with a larger sample size.

Although BMI and lifestyle are also significant factors for Type 2 diabetes mellitus among males in Kolkata, they turned out to be insignificant in females. Most importantly, Whtr performed better in predicting the risk of Type 2 diabetes mellitus for both genders. Hence, based on our observational study in Kolkata, Whtr emerges as a more powerful predictor for predicting the risk of Type 2 diabetes compared to BMI, for both males and females. In the future, we plan to incorporate more anthropometric variables to study the risk of diabetes more comprehensively, based on a larger dataset under a Bayesian framework.

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