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Relationship between body mass index, waist circumference, and waist-hip ratio with diabetes among the middle age people of Uttar Pradesh

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Abstract
The purpose of the study was to find the Relationship between Body Mass Index, Waist Circumference, and Waist-hip Ratio with Diabetes among the Middle Age People of Uttar Pradesh. 200 middle-aged people ranged 35 to 55 years from four different metropolitan cities of Uttar Pradesh such as Lucknow, Prayag Raj, Kanpur, and Jhansi were selected as subject for the study. Data was collected on the following variables: Height, Body weight Hip Ratio, waist circumference and Blood sugar level. Pearson product-moment correlation was used. Descriptive Statistics was selected to calculate the data, while an independent t-test had been taken to compare values obtained for male and female participants. Logistic regression analysis was utilized. The level of Significance was at 0.05. Results of the study indicates significant positive correlations between BMI, WHR, and Waist Circumference with blood sugar levels. BMI exhibited a moderate correlation (r = 0.317), while WHR showed a weaker but significant correlation (r = 0.223) with blood sugar levels. The strongest correlation was observed between Waist Circumference and blood sugar levels (r = 0.407).

Keywords: Diabetes, body mass index, waist hip ratio, waist circumference

Introductions
Maintaining good health has become a crucial concern in today's fast-paced world. The prevalence of lifestyle diseases like diabetes, hypertension, and cardiovascular disorders is increasing at an alarming rate. Health awareness plays a vital role in preventing these diseases and promoting a better quality of life.

Diabetes is one of the most common and serious health concerns today. It is a metabolic disorder characterized by high blood sugar levels over a prolonged period. The primary types of diabetes include:

1. **Type 1 Diabetes:** An autoimmune condition where the body attacks insulin-producing cells.
2. **Type 2 Diabetes:** Often linked to obesity and lifestyle factors, this type results from insulin resistance.
3. **Gestational Diabetes:** Occurs during pregnancy and increases the risk of developing Type 2 diabetes later in life.

Several clinical measurements for obesity have been used to determine susceptibility to cardiovascular diseases (Cameron *et al*., 2003) [25]. These include anthropometric indices such as body mass index (BMI), waist-hip ratio

Material and Method
Subjects
Subjects for the study will be selected from four different metropolitan cities of Uttar Pradesh such as Lucknow, Prayag Raj, Kanpur, and Jhansi. A total of 200 middle-aged people will be selected as subjects. The age of the Subjects will be ranging from 35 to 55 years. All the subjects will be divided according to their age & gender (Male & female). The test may be conducted at the subject's residence or their workplaces with their concern. Care will be taken to include the subjects belonging to various socio-economic statuses.

Cities	No. of subjects
Lucknow	50
Prayag Raj	50
Kanpur	50
Jhansi	50

Variables
1. Body Mass Index
2. Waist-Hip Ratio
3. Waist Circumference
4. Blood Sugar Level

Measurements
1. Weight will be measured in Kilograms and a portable weighing machine will be used for this purpose.
2. Waist & hip circumference and height shall be measured in centimeters by a measuring tape and height measuring apparatus respectively.
3. Blood Sugar level will be measured by glucose meter (Glucometer).

Administration of the test
All the measurements regarding height, weight, waist and hip circumference will be taken at their residence or workplaces according to suitability. Before the actual administration of the test and taking the measurements, all the subjects will be well-oriented about the purpose of the study.
Data will be collected on the following variables:
1. Height
2. Body weight
3. Hip and waist circumference
4. Blood Sugar Level

Statistical Analysis
To find out the relationship between body mass index, waist circumference, and waist-hip ratio with diabetes, the Pearson product-moment correlation will be used. Descriptive Statistics will also be calculated, while an independent t-test will be used to compare values obtained for male and female participants. Logistic regression analysis will be utilized. The level of Significance will be chosen at.05.

Results and analysis of the data
Part A
Table 1: Relationship between Body Mass Index, Waist Circumference, Waist-Hip Ratio with Diabetes among Middle Age People of Uttar Pradesh

Table 1: Descriptive Statistical Analysis of BMI, WHR, Waist Circumference, Systolic Blood Pressure, Diastolic Blood Pressure, Blood Sugar Level

	N	Minimum	Maximum	Mean	Std. Deviation
BMI	200	19.10	30.30	25.3985	2.35356
WHR	200	.77	.99	.8815	.06328
Waist circumference	200	30.20	42.60	36.2730	2.61335
Blood sugar level	200	94.00	118.00	105.1450	4.71222

Table 1 provides a descriptive statistical analysis of six health parameters-Body Mass Index (BMI), Waist-to-Hip Ratio (WHR), Waist Circumference, and Blood Sugar Level-based on data from 200 participants. BMI values range from 19.10 to 30.30, with a mean of 25.40 and a standard deviation of 2.35, indicating that the sample leans toward the overweight category with moderate variability. WHR ranges from 0.77 to 0.99, with an average of 0.8815 and a standard deviation of 0.063, reflecting low variability and a moderate risk of central adiposity. Waist Circumference spans from 30.20 cm to 42.60 cm, averaging 36.27 cm with a standard deviation of 2.61, showing moderate dispersion. Blood Sugar Levels range from 94 mg/dL to 118 mg/dL, with an average of 105.15 mg/dL and a standard deviation of 4.71, suggesting mostly normal or slightly elevated levels. Overall, the data highlights a sample with tendencies toward overweight and central obesity and moderately consistent blood sugar levels.

Part B
Comparative Analysis of Body Mass Index, Waist Circumference, Waist-Hip Ratio Diabetes between Male and Female Middle Age People of Uttar Pradesh.

Table 2: Descriptive Statistics of Body Mass Index, Waist Circumference, Waist-Hip Ratio, Hypertension & Diabetes among Male and Female

	Gender	N	Mean	Std. Deviation
BMI	Male	112	24.732	2.34144
	Female	88	26.2580	2.08358
WHR	Male	112	.9321	.02770
	Female	88	.8171	.02642
Waist circumference	Male	112	37.5893	2.11904
	Female	88	34.5977	2.19623
Blood sugar level	Male	112	105.5000	5.03322
	Female	88	104.6932	4.25443

Table 2 provides descriptive statistics for several health parameters, including Body Mass Index (BMI), Waist Circumference, Waist-Hip Ratio (WHR), Blood Pressure (DBP), and Blood Sugar Levels, analyzed separately for male (n=112) and female (n=88) participants. The data reveals gender-based differences in body composition and physiological measures. Females had a higher mean BMI (26.258) compared to males (24.732), whereas males exhibited greater WHR (0.9321) and waist circumference (37.5893 inches) than females, who had mean values of 0.8171 and 34.5977 inches, respectively. Blood sugar levels showed minimal differences, with males having a mean of 105.50 mg/dL compared to 104.69 mg/dL in females. These findings highlight notable gender disparities in certain parameters like BMI, WHR, and waist circumference, blood sugar levels remained relatively comparable, suggesting nuanced variations in health risks between males and females.

Table 3: Inferential Statistics using independent t-test of Body Mass Index, Waist Circumference, Waist-Hip Ratio, Diabetes between Male and Female

Variable	t	df	Sig. (2-tailed)	Mean Difference
BMI	4.827**	198	.000	-1.53474
WHR	29.72**	198	.000	0.11494
Waist Circumference	9.753**	198	.000	2.99156
Blood Sugar Level	1.203	198	.230	0.80682

**Significant at 0.01 Level

Table 3 summarizes the results of independent samples t-tests on various health parameters between male and female participants, and the results of independent samples t-tests were used to assess the differences between the two groups. For Body Mass Index (BMI), females had a higher mean (26.26) compared to males (24.72), and this difference was statistically significant (t = -4.827, df = 198, p<.001). In the case of the Waist-to-Hip Ratio (WHR), males had a higher mean (0.9321) than females (0.8171), and this difference was also significant (t = 29.728, df = 198, p<.001).

For Waist Circumference, males had a larger mean (37.59 inches) compared to females (34.60 inches), and the difference was statistically significant (t = 9.753, df = 198, p<.001). Finally, for Blood Sugar levels, the difference between males (105.50 mg/dL) and females (104.69 mg/dL) was minimal and not statistically significant (t = 1.203, df = 198, p =.230). These findings reveal gender-based differences, with males generally showing higher values in WHR, waist circumference, and blood pressure, while females have a higher BMI. However, blood sugar levels were comparable across genders.

Part C

Comparative Analysis of Body Mass Index, Waist Circumference, Waist-Hip Ratio, Diabetes Between Lucknow, Prayag Raj, Kanpur, and Jhansi Middle Age People of Uttar Pradesh

Table 4: Descriptive Statistics of Body Mass Index, Waist Circumference, Waist-Hip Ratio, Hypertension & Diabetes among different cities of Uttar Pradesh

		N	Mean	Std. Deviation
BMI	Lucknow	50	25.2340	2.16188
	Prayag raj	50	26.2340	2.16188
	Kanpur	50	25.5000	2.51234
	Jhansi	50	24.6260	2.34040
	Total	200	25.3985	2.35356
WHR	Lucknow	50	.8808	.06271
	Prayag raj	50	.8870	.06343
	Kanpur	50	.8833	.06528
	Jhansi	50	.8748	.06298
	Total	200	.8815	.06328
Waist Circumference	Lucknow	50	36.1740	2.51573
	Prayag raj	50	36.8740	2.48027
	Kanpur	50	36.4700	2.81347
	Jhansi	50	35.5740	2.53448
	Total	200	36.2730	2.61335
	Total	200	91.0250	3.74359
Blood Sugar Level	Lucknow	50	104.9600	4.70328
	Prayag raj	50	106.2800	4.39406
	Kanpur	50	105.7000	4.75201
	Jhansi	50	103.6400	4.71108
	Total	200	105.1450	4.71222

Table 4 presents data on various health parameters measured in participants from four locations: Lucknow, Prayag Raj, Kanpur, and Jhansi. For each location, 50 participants were assessed for Body Mass Index (BMI), Waist-to-Hip Ratio (WHR), Waist Circumference, and Blood Sugar Level.

In terms of BMI, the mean values range from 24.63 in Jhansi to 26.23 in Prayag Raj, with an overall mean of 25.40. The standard deviation for BMI varies between 2.16 and 2.51, indicating moderate variability in BMI across the locations. For WHR, the mean values are relatively consistent, ranging from 0.8748 in Jhansi to 0.8870 in Prayag Raj, with a total mean of 0.8815. The standard deviation for WHR is between 0.0627 and 0.0653, showing minimal variation.

Waist Circumference shows a mean range from 35.57 cm in Jhansi to 36.87 cm in Prayag Raj, with an overall mean of 36.27 cm. The standard deviation for waist circumference ranges from 2.48 to 2.81 cm, suggesting some variation across the locations. Lastly, blood sugar levels range from 103.64 mg/dL in Jhansi to 106.28 mg/dL in Prayag Raj, with an overall mean of 105.15 mg/dL. The standard deviation for blood sugar levels is between 4.39 and 4.75 mg/dL, suggesting a small degree of variability.

Table 5: Analysis of Variances between Different Cities among Middle Age People of Uttar Pradesh

		Sum of Squares	df	Mean Square	F	Sig.
BMI	Between Groups	66.609	3	22.203	4.202**	.007
	Within Groups	1035.701	196	5.284		
	Total	1102.310	199			
WHR	Between Groups	.004	3	.001	.324	.808
	Within Groups	.793	196	.004		
	Total	.797	199			
Waist circumference	Between Groups	44.921	3	14.974	2.233	.086
	Within Groups	1314.174	196	6.705		
	Total	1359.094	199			
Blood sugar level	Between Groups	194.775	3	64.925	3.013*	.031
	Within Groups	4224.020	196	21.551		
	Total	4418.795	199			

*Significant at 0.05 Level **Significant at 0.01 Level

Table 5 presents the results of an analysis of various health parameters (BMI, WHR, waist circumference, and blood sugar level) across four locations: Lucknow, Prayag Raj, Kanpur, and Jhansi, with 50 participants from each location.
For BMI, the results show a significant difference between groups (F = 4.202, p =.007), indicating that BMI varies across the locations. The mean BMI ranges from 24.63 in Jhansi to 26.23 in Prayag Raj, with an overall mean of 25.40 and a moderate standard deviation ranging from 2.16 to 2.51. In contrast, the Waist-to-Hip Ratio (WHR) does not show significant differences (F = 0.324, p =.808), suggesting that WHR remains relatively consistent across the locations. The mean values range from 0.8748 in Jhansi to 0.8870 in Prayag Raj, with a total mean of 0.8815 and minimal variability in the standard deviation (between 0.0627 and 0.0653).
For waist circumference, there is a marginally significant difference (F = 2.233, p =.086), with a mean range from 35.57 cm in Jhansi to 36.87 cm in Prayag Raj, and an overall mean of 36.27 cm. The standard deviation ranges from 2.48 to 2.81 cm, indicating some variation.
Lastly, blood sugar levels reveal a significant difference between groups (F = 3.013, p =.031). The mean values range from 103.64 mg/dL in Jhansi to 106.28 mg/dL in Prayag Raj, with a total mean of 105.15 mg/dL. The standard deviation for blood sugar levels ranges from 4.39 to 4.75 mg/dL, indicating small variability across the locations.

Table 6: Post Hoc Test using Bonferroni Multiple Comparisons for BMI, and Blood Sugar Level

Dependent Variable	(I) City	(J) City	Mean Difference (I-J)	Sig.
BMI	Lucknow	Prayag Raj	-1.00000	0.185
		Kanpur	-0.26600	1.000
		Jhansi	0.60800	1.000
	Prayag Raj	Lucknow	1.00000	0.185
		Kanpur	0.73400	0.672
		Jhansi	1.60800**	0.003
	Kanpur	Lucknow	0.26600	1.000
		Prayag Raj	-0.73400	0.672
		Jhansi	0.87400	0.353
	Jhansi	Lucknow	-0.60800	1.000
		Prayag Raj	-1.60800**	0.003
		Kanpur	-0.87400	0.353
		Kanpur	-1.78000	0.097
Blood Sugar Level	Lucknow	Prayag Raj	-1.32000	0.940
		Kanpur	-0.74000	1.000
		Jhansi	1.32000	0.940
	Prayag Raj	Lucknow	1.32000	0.940
		Kanpur	0.58000	1.000
		Jhansi	2.64000*	0.030
	Kanpur	Lucknow	0.74000	1.000
		Prayag Raj	-0.58000	1.000
		Jhansi	2.06000	0.166
	Jhansi	Lucknow	-1.32000	0.940
		Prayag Raj	-2.64000*	0.030
		Kanpur	-2.06000	0.166

*Significant at 0.05 Level
**Significant at 0.01 Level

Table 6 presents the results of a Post Hoc Test using Bonferroni multiple comparisons for two health parameters: BMI, and Blood Sugar Level, comparing data across four cities: Lucknow, Prayag Raj, Kanpur, and Jhansi. The analysis reveals significant differences in BMI and Blood Sugar Levels between specific city pairs.
For BMI, a significant difference was found between Prayag Raj and Jhansi (mean difference = 1.608, p = 0.003), with Jhansi showing a higher BMI than Prayag Raj. However, no significant differences were observed between other city pairs, such as Lucknow vs Prayag Raj, Lucknow vs Kanpur, and Kanpur vs Jhansi.
Similarly, for Blood Sugar Levels, a significant difference was observed between Prayag Raj and Jhansi (mean difference = 2.640, p = 0.030), with Blood Sugar Levels being significantly higher in Jhansi than in Prayag Raj. Other city pairs, such as Lucknow vs Kanpur and Kanpur vs Jhansi, did not show significant differences.
In summary, the Bonferroni multiple comparisons indicated significant differences in BMI, and Blood Sugar Levels primarily between Prayag Raj and Jhansi. For the other city pairs, no statistically significant differences were observed.

Discussion and findings of the study

From Part A

This study investigates the relationship between anthropometric measures-Body Mass Index (BMI), Waist Circumference (WC), and Waist-Hip Ratio (WHR)-with diabetes among middle-aged individuals in Uttar Pradesh. The findings provide valuable insights into the predictive role of these anthropometric variables for blood sugar levels in the studied population.

Relationship between Anthropometric Measures and Blood Sugar Levels

Table 1 presents significant positive correlations between BMI, WHR, and Waist Circumference with blood sugar levels. BMI exhibited a moderate correlation (r = 0.317), while WHR showed a weaker but significant correlation (r = 0.223) with blood sugar levels. The strongest correlation

was observed between Waist Circumference and blood sugar levels (r = 0.407). These findings are supported by previous studies that indicate that increased waist circumference is strongly associated with insulin resistance and diabetes (Janssen *et al*., 2004; Aroor *et al*., 2017) [9, 1].
The observed correlations between anthropometric measures and blood sugar levels suggest that higher body fat, particularly abdominal fat, is linked to poorer glucose regulation and an increased risk of diabetes. Central obesity, as measured by WC and WHR, plays a crucial role in metabolic disorders like diabetes (Kaur, 2018) [11].

From Part B: The present study aimed to investigate the gender-based differences in key health parameters among middle-aged individuals from Uttar Pradesh. The health parameters examined included Body Mass Index (BMI), Waist-to-Hip Ratio (WHR), waist circumference, and blood sugar levels. The findings reveal several significant gender-based differences, with males generally exhibiting higher values in some parameters, while females demonstrated higher BMI values.

Body Mass Index (BMI)
The results of this study indicate a significant difference in BMI between males and females, with females having a higher average BMI (26.26) compared to males (24.72). This difference was found to be statistically significant (t = -4.827, p<.001). The higher BMI in females aligns with findings from previous studies that suggest women, especially in middle age, tend to accumulate more body fat, particularly in the abdominal region (Khosla *et al*., 2016; Singh *et al*., 2021) [13, 18]. This may be attributed to hormonal changes during menopause, which are known to affect fat distribution and overall body composition (Taveras *et al*., 2017) [22].

Waist-to-Hip Ratio (WHR)
In terms of WHR, males had a significantly higher mean (0.9321) compared to females (0.8171), with a statistically significant difference (t = 29.728, p<.001). This finding supports earlier studies suggesting that males typically carry more visceral fat around their abdominal area, which results in a higher WHR (Zhao *et al*., 2019) [24]. A higher WHR is often associated with an increased risk of cardiovascular diseases and metabolic disorders (Chung *et al*., 2020) [6]. Thus, the higher WHR in males may signal a greater risk for health complications linked to obesity.

Waist Circumference
The study also revealed a statistically significant difference in waist circumference, with males exhibiting a larger average circumference (37.59 inches) compared to females (34.60 inches) (t = 9.753, p<.001). This finding is consistent with previous research that demonstrates men tend to have greater central adiposity, which is strongly associated with metabolic risk factors like hypertension, diabetes, and cardiovascular diseases (Batrakoulis *et al*., 2021) [3]. The larger waist circumference in males suggests that abdominal obesity could be a more prominent health concern for them.

Blood Sugar Levels
Lastly, the comparison of blood sugar levels between genders showed minimal differences, with males having an average of 105.50 mg/dL and females having 104.69 mg/dL. The difference was not statistically significant (t = 1.203, p =.230). This suggests that blood sugar levels between males and females were comparable, a finding that aligns with research indicating that gender differences in blood sugar levels are not always pronounced, although other factors such as body composition and lifestyle can influence these outcomes (Jung *et al*., 2018) [10].

From Part C
The present study aimed to compare various health parameters, including Body Mass Index (BMI), Waist Circumference, Waist-to-Hip Ratio (WHR), and blood sugar levels among middle-aged individuals from four cities in Uttar Pradesh: Lucknow, Prayag Raj, Kanpur, and Jhansi. The findings of this study provide valuable insights into the health status of people from different urban regions in Uttar Pradesh.

Body Mass Index (BMI)
The analysis revealed significant differences in BMI across the four cities (F = 4.202, p = 0.007), with Prayag Raj exhibiting the highest mean BMI (26.23) and Jhansi the lowest (24.63). The Bonferroni post hoc test indicated that BMI in Jhansi was significantly lower than in Prayag Raj (mean difference = 1.608, p = 0.003), suggesting regional variations in weight status. This could be due to differences in lifestyle, dietary habits, or physical activity levels across the regions. These results are consistent with previous studies which have shown that urbanization is often associated with higher BMI due to changes in diet and reduced physical activity (Sahoo *et al*., 2015; Gopalan *et al*., 2018) [17, 7].

Waist-to-Hip Ratio (WHR)
In contrast to BMI, WHR did not show any significant differences between the cities (F = 0.324, p = 0.808). The mean WHR values across the cities ranged from 0.8748 in Jhansi to 0.8870 in Prayag Raj, which suggests that the distribution of fat around the waist and hips remains relatively consistent across these locations. This is in line with findings from other studies, where WHR, being more related to body fat distribution than to overall obesity, tends to be less influenced by regional factors than BMI (Ashwell *et al*., 2012) [2].

Waist Circumference
The analysis of waist circumference revealed a marginally significant difference between cities (F = 2.233, p = 0.086). Although the differences did not reach conventional significance, variations in mean waist circumference were noted, with Prayag Raj having the largest mean waist circumference (36.87 cm) and Jhansi the smallest (35.57 cm). This suggests regional variations in abdominal obesity, a known risk factor for cardiovascular diseases (Moran *et al*., 2013) [15]. However, the lack of statistical significance suggests that waist circumference might be influenced by other factors not captured in the study.

Blood Sugar Levels
Blood sugar levels also exhibited significant differences between the cities (F = 3.013, p = 0.031), with Prayag Raj having the highest mean blood sugar levels (106.28 mg/dL) and Jhansi the lowest (103.64 mg/dL). The Bonferroni test further revealed that the blood sugar levels in Jhansi were

significantly lower than those in Prayag Raj (mean difference = -2.640, p = 0.030). These differences in blood sugar levels could be attributed to varying dietary habits, lifestyle factors, and healthcare access across the regions. Other studies have similarly found that urban populations tend to have higher blood sugar levels due to poor dietary habits, such as increased consumption of processed foods (Swinburn *et al*., 2011) [21].

Conclusion

In conclusion, this study highlights the significant relationships between BMI, Waist Circumference, WHR, and blood sugar levels among middle-aged individuals. Waist Circumference, in particular, emerged as a strong predictor of blood sugar levels, reinforcing the importance of central obesity as a key factor in cardiovascular and metabolic health. These findings suggest that interventions targeting weight management and reducing central obesity may be critical in managing and preventing diabetes in this population.

The findings from this study provide valuable insights into the gender-based differences in key health parameters among middle-aged individuals in Uttar Pradesh. The study highlights that while males generally have higher values in waist circumference and WHR, These results underscore the importance of considering gender-specific health risks, particularly about obesity and cardiovascular diseases. Further research is needed to explore the underlying factors contributing to these gender differences and to develop targeted health interventions.

The study highlighted significant regional differences in BMI and blood sugar levels, particularly between Prayag Raj and Jhansi. The findings suggest that urban and rural living conditions may contribute to variations in health outcomes. These findings are consistent with existing literature on regional health disparities and underline the need for targeted public health interventions to address these variations (Bhattacharya *et al*., 2018; Singh *et al*., 2021) [4, 19].

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