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The Correlation of Waist-to-Hip Ratio and Sleep Quality with Fasting Blood Glucose in Type 2 Diabetes Mellitus Patients

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Abstract: Type 2 diabetes mellitus (T2DM) is characterized by uncontrolled blood sugar levels and is diagnosed using fasting blood glucose (FBG) measurements. Risk factors for T2DM include central obesity, measured by the waist-to-hip ratio (WHR), and poor sleep quality. This study aimed to determine the relationship between WHR and sleep quality with FBG levels in T2DM patients, by employing an observational study with a cross-sectional design A total of 51 respondents aged 45–75 years were selected using purposive sampling. Waist and hip circumference were measured with a metline; sleep quality was assessed using a Pittsburgh Sleep Quality Index (PSQI) questionnaire, and FBG levels were obtained from secondary data in the form of medical records at the Karangmalang Community Health Center. Spearman was used for the bivariate test, while the multiple linear regression was used for the multivariate test. The test results showed a significant relationship between WHR and FBG levels (p=0.001, r=0.460), and between sleep quality with FBG levels (p<0.001, r=0.553). Multivariate results obtained p=0.026 for sleep quality and p=0.093 for WHR, suggesting sleep quality is more strongly associated with FBG levels. Sleep quality was the dominant factor associated with FBG levels in T2DM patients. The results of this study can be used as a guideline for individuals with T2DM to maintain normal blood glucose levels and good sleep quality for better blood glucose control.

Keywords: fasting blood sugar, sleep quality, type 2 diabetes mellitus, waist-to-hip ratio

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INTRODUCTION

Diabetes Mellitus (DM) is a metabolic disease that poses a global health risk, characterized by high blood sugar levels or hyperglycemia. This occurs due to abnormalities in insulin function, insulin secretion, or both. DM is classified into gestational diabetes, type 1 diabetes mellitus (T1DM), type 2 diabetes mellitus (T2DM), and other specific diseases (Perkeni, 2021). Uncontrolled blood sugar levels in T2DM patients mainly resulted from pancreatic beta cells' dysfunction, which impairs insulin sensitivity. Since insulin functions to balance blood glucose levels, excess carbohydrate intake can lead to hyperglycemia when insulin cannot effectively balance blood glucose levels. Adults and the elderly account for 80% of T2DM patients (Safitri et al., 2023). These patients face the risk of developing cardiovascular complications such as brain disorders, heart and blood vessel disease, and microvascular complications such as eye and kidney disease (Perkeni, 2021).

The prevalence of DM continues to increase every year. In Indonesia, it reached 877.531 people (1.7%) based on doctors' diagnosis and is estimated to reach 194 million by 2030. In Central Java, the prevalence of DM was 118.184 people (1.8%); in Sragen Regency, it was 23.784 people (3.1%) in 2022 (Dinas Kesehatan Kabupaten Sragen, 2022; Kemenkes RI, 2023). Globally, T2DM accounts for 90% of DM cases, making it the most common type of DM. By 2025, T2DM is expected to become the 8th leading cause of death, burden of disease, and is forecasted to rank second globally by 2050 (International Diabetes Federation, 2025). The diagnosis of T2DM is often made by measuring fasting blood sugar (FBG) levels. According to Yusuf et al. (2023), FBG measures blood glucose levels in plasma after an approximately 8-hour fast. Fasting prevents the ingestion of food, allowing the body to maintain blood sugar levels in peripheral tissues, the liver, and hormones, which impact blood sugar levels. The control of FBG is impacted by several factors, such as mental health, clinical status, behavior, and lifestyle. Mental and clinical factors include family history, stress, and obesity, while behavior and lifestyle factors include sleep quality, alcohol consumption, smoking, diet, and physical activity (Rusdani et al., 2022).

Central obesity can lead to insulin resistance. Free fatty acids are more rapidly transported through the bloodstream, which increases blood sugar levels and impaired insulin absorption, potentially leading to T2DM (Yunita et al., 2022). Centrally obese individuals with T2DM are at higher risk of complications such as cardiovascular disease and stroke (Fitria et al., 2022). The waist-to-hip ratio (WHR) is an effective indicator of central obesity and reflects body fat distribution. Body fat located in the abdominal area is known as visceral fat, while body fat located in the pelvic area is known as subcutaneous fat (Dewi et al., 2022). Research by Septiana and Junita (2025) showed a relationship between WHR and FBG levels with p-value=0.001.

Sleep quality is a risk factor that can increase FBG levels. Sleep significantly impacts sleep quality and normal glucose homeostasis; short sleep duration can impair glucose utilization and tolerance (Tajiwalar et al., 2023). In individuals with T2DM, sleep disturbances increase the frequency of awakenings and difficulties falling back asleep, which often lead to poor sleep quality. Decreased sleep quality can cause endocrine and metabolic disorders, including insulin resistance, reduced insulin response, and impaired glucose tolerance (Sari et al., 2023). Research conducted by Basir and Misnarsilah (2020) found a notable relationship between sleep quality and FBG in individuals with T2DM, with p-value=0.004. However, no previous studies have examined the relationship between

WHR and sleep quality simultaneously as predictive factors of FBG in T2DM patients. This study aimed to determine the relationship between WHR and sleep quality with FBG levels in individuals with T2DM.

METHODS

Design, Time, and Place

This research employed an observational, cross-sectional design. It was conducted at the Karangmalang Community Health Center, Sragen Regency, Central Java Province, in February 2025. Ethical approval was obtained from the Health Research Ethics Committee of Dr. Moewardi Hospital with No. 173/I/HREC/2025.

Population and Sample

The population comprised all T2DM patients in the Karangmalang Community Health Center, totaling 1,785 individuals in 2022 (Dinas Kesehatan Kabupaten Sragen, 2022). The sample consisted of 51 respondents, obtained using the Lemeshow formula (Lemeshow & David, 1997), with a 10% dropout rate; the formula was n= (〖z_(1-α/2)〗 ^2 PQ)/d^2 . Samples were obtained through purposive sampling. The inclusion criteria were outpatients suffering from T2DM, aged 45-75 years, male or female, willing to be respondents, able to communicate effectively, and engaged in Prolanis activities at the Karangmalang Community Health Center. In contrast, the exclusion criteria in this study were T2DM patients who did not attend during data collection or who had changed addresses.

Research Procedure and Instrument

This study used a metline to measure waist and hip circumference, a questionnaire, and the Pittsburgh Sleep Quality Index (PSQI) to assess respondents' sleep quality. FBG level data were obtained from medical records at the Karangmalang Community Health Center. The PSQI questionnaire has good reliability and validity, as indicated by the value of Cronbach's alpha of 0.72 (Coskun, 2023; Setyowati & Chung, 2020).

Data Processing and Analysis

The normality of the data was assessed using the Kolmogorov-Smirnov test. Results indicated that the FBG and WHR level data are not normally distributed, while the sleep quality data are normally distributed; consequently, the Spearman test was used for bivariate analysis to measure the relationship between variables, and the multivariate analysis used was multiple linear regression. This test aimed to determine the variables most strongly associated with FBG levels in T2DM patients. The study used a 95% confidence level, and all data were analyzed with SPSS version 23.

RESULTS

Respondent Characteristics

Respondent characteristics data were obtained through a questionnaire that included gender, age, smoking habits, alcohol consumption, and family history. In this study, WHR was categorized as normal (≤0.85) or at-risk (>0.85) for females and normal (≤0.90) or at-risk (>0.90) for males. Sleep quality was assessed using the total PSQI score and categorized as good (≤5) or poor (>5). FBG levels

were obtained from the medical records at the Karangmalang Health Center and categorized as normal (80-130 mg/dl) or high (>130 mg/dl).

Table 1

Characteristics of respondents

Characteristics of respondents	Frequency (n)	Percentage (%)
Gender		
Male	10	19.60
Female	41	80.40
Age Group		
Age 46-55	3	6.00
Age 56-65	36	70.50
Age >65	12	23.50
Smoking Habit		
Yes	9	17.60
No	42	82.40
Alcohol Consumption		
Yes	0	0
No	51	100
Family History of T2DM		
Yes	49	96.10
No	2	3.90
Total	51	100

Table 1 shows that 41 (80.4%) respondents were female, while 10 (19.6%) were male. There were 3 (5.8%) respondents aged 46-55 years, 36 (70.5%) aged 56-65 years, and 12 (23.5%) aged >65 years. A total of 42 (82%) respondents did not smoke, and 9 (17.6%) smoked. All respondents (100%) did not consume alcohol. Additionally, 49 (96.1%) respondents reported a family history of T2DM, whereas 2 (3.9%) reported no family history.

Table 2

Result of the WHR, sleep quality, and FBG levels

Variable	Frequency (n)	Percentage (%)	Mean±SD	Minimum	Maximum
WHR					
Male normal	2	3.90	0.89±0.01	0.89	0.90
Male at risk	8	15.70	0.93±0.01	0.92	0.95
Female normal	4	7.80	0.85±0.00	0.84	0.85
Female at risk	37	72.50	0.91±0.39	0.86	0.96
WHR average			0.91±0.03	0.84	0.96
Sleep quality					
Good	6	11.80	4.50±0.39	3	5
Poor	45	88.20	8.70±1.95	6	14
Sleep quality average			8.24±2.30	3	14
FBG levels (mg/dl)					
Normal	2	3.90	118±1.41	117	119
High	49	96.10	175±43.53	132	321
FBG levels average			172±44.00	117	321

Table 2 indicates that most female respondents were classified in the risk category, totaling 37 individuals (72.5%), with a mean WHR of 0.91±0.39 and values ranging from 0.86 to 0.96. Only 4 female respondents (7.8%) fell into the normal category, showing an average WHR of 0.85±0.00 with a range of 0.85–0.86. Among male respondents, 8 individuals (15.7%) were categorized as at risk, with a mean WHR of 0.93±0.01 and WHR values between 0.92 and 0.95. In contrast, 2 male respondents (3.9%) were in the normal category, presenting an average WHR of 0.89±0.01 and a range of 0.89–0.90.

The mean WHR of all respondents was 0.91±0.03, with values ranging from 0.84 to 0.96. In terms of sleep quality, many respondents exhibited poor sleep quality, accounting for 45 individuals (88.2%), with a mean score of 8.7±1.95 and a range of 6–14. In contrast, only 6 respondents (11.8%) had good sleep quality, with an average score of 4.5±0.39 and scores ranging from 3 to 5. Overall, the mean sleep quality score among respondents was 8.24±2.30, with minimum and maximum scores of 3 and 14, respectively. Regarding fasting blood glucose (FBG) levels, almost all respondents, 49 individuals (96.1%) were classified as having elevated FBG levels, with a mean value of 175±43.53 mg/dL and a range of 132–321 mg/dL. Only 2 respondents (3.9%) had normal FBG levels, with an average of 118±1.41 mg/dL, ranging from 117 to 119 mg/dL. Overall, the mean FBG level among all respondents was 172±44.08 mg/dL, with values ranging from 117 to 321 mg/dL.

Correlation of WHR and Sleep Quality with FBG Levels

There was a significant relationship between WHR and fasting blood glucose levels among patients with diabetes mellitus (p=0.001). The correlation analysis showed a moderate positive association (r=0.460), indicating that a higher-risk WHR tends to be accompanied by increased fasting blood glucose levels. In addition, there was a significant relationship between sleep quality and fasting blood glucose levels in patients with diabetes mellitus (p<0.001). The correlation coefficient (r=0.553) demonstrated a moderate association, suggesting that poorer sleep quality is associated with higher fasting blood glucose levels.

Table 3

Bivariate Analysis

Variable	FBG Normal		FBG High		Total	r	*p-value*
	n	%	n	%			
WHR							
Normal	2	3.90	4	7.90	6		
At risk	0	0.00	45	88.20	45	0.460	0.001*
Total	2	3.90	49	96.10	51		
Sleep quality							
Good	2	3.90	4	7.90	6		
Poor	0	0.00	45	88.20	45	0.553	<0.001*
Total	2	3.90	49	96.10	51		

*) Statistically significant data (p<0.05). r= coefficient correlation

Multivariate analysis aims to determine the relationship between waist-to-hip circumference ratio (WHR) and sleep quality with fasting blood sugar levels in T2DM patients. The results indicate

that WHR has a significance value of 0.093, while sleep quality has a significance value of 0.026. This suggests that sleep quality is more strongly associated with FBG levels.

Table 4

Multivariate Analysis

Variable	p-value
WHR	0.093
Sleep quality	0.026*

*) Statistically significant data (p<0.05).

DISCUSSION

Respondent Characteristics

The majority of respondents in this study were female, accounting for 80.4%, with 41 participants. Females have a higher risk of developing T2DM than males because estrogen hormones may interfere with iodine absorption in the intestines. This prevents myelin formation in nerves, potentially leading to diabetic neuropathy. Moreover, females are also more likely to develop T2DM, which is complicated by diabetic neuropathy. Menstrual cycles and menopause further contribute to fat accumulation, which inhibit the process of transporting glucose into cells (Natawirarindry et al., 2022).

Most respondents in this study were aged 56-65 years, accounting for 70.5%, with 36 participants. The risk of developing T2DM increases with age. As people age, bodily functions change, including changes in pancreatic cells, which contribute to the diabetes epidemic. Aging results in a decline in electrical activity in ATP-sensitive pancreatic beta cell channels, disrupting insulin secretion, leading to increased blood glucose levels (Tuduri et al., 2022).

A total of 42 (82.4%) respondents did not smoke. Cigarettes are products made from tobacco (Nicotiana tabacum) that are burned and smoked, such as crutu and kretek cigarettes. The nicotine content in cigarettes decreases insulin secretion in the pancreas and can increase the incidence of T2DM (Yazia & Suryani, 2023). The hormones adrenaline, dopamine, and insulin are significantly affected by nicotine. The nicotine contained in cigarettes affects cortisol levels. This occurs due to the release of the hormone cortisol, which increases blood sugar levels. This increase in blood sugar levels is caused by the hormone cortisol stimulating glycogenolysis in the liver, muscles, and fat, thereby disrupting insulin function (Fajriati, 2021).

None of the 51 respondents in this study consumed alcohol. According to Muchtar et al. (2023), the alcohol consumed may elevate FBG levels. Alcohol affects insulin function, resulting in an increase in FBG. This occurs because alcohol contains carbohydrates and can raise blood sugar levels. Furthermore, alcohol promotes fat oxidation, which inhibits the process of burning fat and calories, thus increasing the risk of central obesity and FBG levels (Da et al., 2023).

Many respondents in this study had a family history of T2DM, with 49 people (96.1%). According to Rediningsih and Lestari (2022), individuals with a family history of T2DM have an 11.074-fold

higher risk of developing T2DM than those without such a history. This is influenced by the complex interaction between an individual's unhealthy lifestyle and genetics, which can increase the incidence of T2DM. Research conducted by Fradina and Nugroho (2020) reported that children of parents with DM are at higher risk of developing T2DM. The closer the family relationship, the greater the risk of developing T2DM.

Most respondents in this study were female and classified as being at risk of obesity, accounting for 37 individuals (71.5%). This condition may be partly attributed to low levels of physical activity, as many respondents spent most of their time at home caring for their grandchildren, which limited opportunities for energy expenditure. Consequently, excess energy was stored as fat, particularly in the abdominal region, leading to central obesity. Excess adipose tissue disrupts metabolic processes by altering adipokine secretion, thereby increasing the risk of cardiometabolic complications. Elevated adipokine levels can induce glucotoxicity in pancreatic β-cells, contributing to insulin resistance and β-cell dysfunction, which ultimately impairs glucose metabolism and elevates fasting blood glucose (FBG) levels (Septiana & Junita, 2025). Furthermore, obesity is closely associated with aging; increasing age is accompanied by changes in body composition and physiological function, resulting in greater abdominal fat accumulation and hormonal alterations (Khairani et al., 2024). Among older adults, obesity is also influenced by eating patterns, metabolic changes, and reduced physical activity.

Poor sleep quality was reported by the majority of respondents, affecting 45 individuals (88.2%). Previous studies have shown that symptoms of type 2 diabetes mellitus (T2DM) play a significant role in deteriorating sleep quality (Yazia & Suryani, 2023). Common complaints among individuals with T2DM include excessive hunger, persistent thirst, frequent urination, pain, and itching, all of which are linked to elevated blood glucose levels. Hyperglycemia promotes glucose excretion through the kidneys, increasing urine production and fluid loss, which in turn triggers thirst and nocturnal awakenings to urinate. In this study, respondents frequently reported disrupted sleep due to nocturia, pain, and persistent thirst, highlighting the bidirectional relationship between sleep disturbances and glycemic control.

Most respondents also demonstrated elevated fasting blood glucose levels, with 40 individuals (96.1%) classified as having high FBG. Fasting prior to blood glucose measurement is essential to reflect the regulation of plasma glucose in peripheral tissues, the liver, and hormonal systems. In general, excessive dietary sugar intake contributes to hyperglycemia, which arises from impaired insulin secretion, reduced insulin sensitivity, or a combination of both (Yazia & Suryani, 2023). Carbohydrates consumed as glucose are stored as glycogen in skeletal muscle and the liver, and repeated intake stimulates continuous insulin release. Insulin facilitates the transport of glucose into cells; in its absence or dysfunction, glucose uptake is impaired, resulting in elevated blood glucose levels.

Correlation of WHR and Sleep Quality with FBG Levels

The findings of this study (Table 3) indicate that 45 respondents exhibited both high-risk WHR and elevated FBG levels.. The analysis revealed a p-value of 0.001, indicating a significant relationship between WHR and FBG levels in T2DM patients. The correlation coefficient (r) was 0.460, suggesting

a moderate relationship. The results also demonstrated a positive relationship, meaning that higher WHR risk levels were associated with increased FBG levels. This aligns with research by Septiana and Junita (2025) which found a significant correlation between WHR and FBG levels with a p-value of <0.001. The study also found that individuals with central obesity had a higher risk of developing T2DM. The correlation between WHR and FBG levels reflects visceral fat in the body, where visceral fat can reduce the production of anti-atherogenic adipokines that have a protective effect. This may contribute to metabolic disorders, including insulin resistance and increased blood sugar levels (Anas et al., 2024).

Insulin resistance in individuals with central obesity occurs due to changes in the body's cells. Someone with insulin resistance has blood glucose that cannot be properly absorbed by the body's cells. This can increase blood glucose levels and elevate the risk of T2DM (Natawirarindry et al., 2022). Central obesity leads to insulin ineffectiveness in the blood, preventing blood glucose from entering cells. This resistance prompts the body to produce more insulin, thus increasing blood insulin levels (Muchtar et al., 2023).

Based on the study results (Table 3), a total of 45 respondents were identified as having poor sleep quality in conjunction with elevated fasting blood glucose levels. The analysis results reveal a value of p<0.001, demonstrating a significant relationship between sleep quality and FBG levels in individuals with T2DM. The correlation coefficient (r) was 0.553, indicating a moderate relationship between the variables. The analysis also showed a positive relationship, meaning that poorer sleep quality leads to higher FBG levels. This research aligns with research by Nugraha et al. (2022), which reported a relationship between sleep quality and fasting blood sugar levels with a p-value of 0.003. Good sleep quality supports the formation of new cells, regenerates damaged cells, provides time for the body to rest, and protects the body's biochemical balance. According to (Tajiwalar et al., 2023), sleeping less than 4 hours for 6 consecutive days can increase cortisol secretion, glucose tolerance, and help decrease leptin secretion. Leptin is a hormone that promotes feelings of fullness, while ghrelin is an appetite-stimulating hormone. Blood glucose significantly affects sleep quality due to changes in hormonal function from the activity of the sympathetic nervous system. This induces glucocorticoid secretion, such as cortisol, leading to insulin resistance and glucose intolerance.

The multiple linear regression analysis indicated that sleep quality was the factor most related to FBG levels in T2DM patients, with a p-value of 0.026. These results align with research by (Basir & Misnarliah, 2020), which found a significant relationship between sleep quality and fasting blood glucose levels in individuals with T2DM. This is because sleep quality influences catecholamine production in the sympathetic nervous system. Furthermore, sleep quality also affects the production of epinephrine and norepinephrine, as well as the release of melatonin. Poor sleep quality was attributed to frequent urination at night in individuals with T2DM. This disrupts sleep patterns and reduces sleep quality, thereby increasing FBG levels. Poor sleep quality in individuals with T2DM can impact energy balance through irregular mealtimes, decreased energy expenditure, and increased appetite. Individuals with poor sleep quality experience decreased leptin levels and increased ghrelin levels, hormones associated with appetite regulation. This increased appetite can lead to obesity and insulin resistance (Bingga, 2021; Nugraha et al., 2022).

Despite its limitations, particularly the limited availability of prior studies as references for multiple linear regression analysis, this study provides valuable insight into the relationship between WHR, sleep quality, and fasting blood glucose levels in patients with T2DM. The findings highlight the importance of monitoring WHR and maintaining good sleep quality as practical, non-pharmacological strategies to support glycemic control and overall health. Alongside dietary management and physical activity, optimizing WHR and sleep quality may play a key role in T2DM management. Future studies are encouraged to include additional variables related to blood glucose regulation and to further compare findings using multiple linear regression approaches.

CONCLUSION

Respondent characteristics: Most of the respondents in this study were female, aged 56-65 years, did not consume alcohol or smoke, and had a family history of T2DM. Most of the female respondents were at risk of obesity based on the results of the WHR (72,5%), reported a poor sleep quality (88,2%), and had elevated FBG level (96,1%). The results of the analysis demonstrate that there is a significant relationship between WHR and FBG levels (p=0.001) and sleep quality with FBG levels (p<0,001) in T2DM patients. The multivariate analysis showed that sleep quality was the variable most strongly associated with FBG levels in patients with T2DM (p=0.026). It is recommended that T2DM patients continuously monitor and improve their WHR and sleep quality to maintain FBG levels. Suggestions for future researchers include comparing previous studies related to multiple linear regression tests.

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Author Contribution Statement

Arif Budi Santoso: Conceptualization, Data curation, Formal analysis, Resources, Investigation, Validation, and Writing-original draft. **Kezia Elian Devina**: Conceptualization, Data curation, Supervision, Validation, and Writing-reviewing draft. **Dyah Ayu Kusuma Wardani**: Data curation, Validation, and Supervision.

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