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Original Article

Diabetes Predictive Scoring Model in Adults at Jakarta Based on Waist-to-Hip Ratio and Handgrip Strength

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ABSTRACT

Background: Diabetes mellitus is an escalating public health concern, particularly among productive-age populations in urban settings. This study aimed to evaluate the potential of WHR and HG as low-cost, non-invasive tools for early diabetes risk detection.
Methods: A cross-sectional study was conducted among 539 productive-age adults (>18 years) across multiple districts in Jakarta during 2024–2025 using consecutive sampling. Fasting blood glucose, WHR, and HG were assessed. Multiple linear regression was applied to examine associations between WHR, HG, and fasting glucose. A binary logistic regression model with backward likelihood ratio selection was used to identify predictors of diabetes.
Results: WHR showed a significant positive association with fasting glucose (B = 72.647; p = 0.001), while HG demonstrated a significant inverse association (B = –0.468; p = 0.047). Logistic regression analysis indicated that lower HG (B = –0.867; Exp(B) = 0.420; p = 0.001) and higher WHR (B = –2.413; Exp(B) = 0.090; p = 0.018) were independently associated with diabetes risk. The model constant was 4.535 (p < 0.001).
Conclusion: A model integrating WHR and HG shows promise for early diabetes risk stratification among productive-age adults in Jakarta, supporting their utility in community-based screening.

INTRODUCTION

Diabetes mellitus (DM) is one of the most serious and growing global healthcare concerns of the 21st century. It encompasses a complex, multifaceted condition with broad-spectrum implications that extend beyond difficulties with glycemic control. The constantly rising number of diabetic patients over the past few decades has transformed the concern associated with the condition from being just healthcare to being one of the significant challenges to global growth in terms of healthcare infrastructures, working populations, and longevity worldwide. According to the latest data by the International Diabetes Federation (IDF), in 2021, there were

536.6 million adults aged 20–79 years living with diabetes, amounting to 10.5% of the total adult global populations, while it was expected to rise to 783.2 million (12.2%) by 2045, marking a clearly exponential graph that still trails behind healthcare-related growth across the globe. Despite being comparable in terms of percentages for women and men, the maximum drain in communities with growing diabetic populations has been among older adults, specifically in the 75–79 age group. [1,2]

Among the rising global trend of diabetes mellitus cases, the Southeast Asia Region has been one of the most worrisome areas, owing to the complex interplay between rapidly growing urban centers and regional development, the impending demographic transition in the region, and the nation's growing aging population. Based on current projections, it is estimated that there are more than 88 million adults with the condition in the region, accounting for nearly 9% of the total adult population. Projections indicate a 68% increase in cases, reaching 152 million by 2045. The regional burden is further compounded by the fact that nearly 51.2% of cases remain undiagnosed, positioning Southeast Asia among the top three regions globally with the highest proportion of undetected diabetes. This silent epidemic contributes to delayed diagnosis and late presentation with complications, amplifying morbidity and mortality. As the most populous nation in the region, Indonesia exemplifies this dual challenge of high prevalence and delayed detection, with current estimates showing a national prevalence of 19.5%, projected to rise to 28.6% by 2045. [3,4]

Despite the growing incidence of Type 2 diabetes mellitus (T2DM) worldwide, there is an evolving demand for simplified, easily accessible, and less expensive methods of detecting the condition in regions where contemporary detection methods are not readily available. Considering glycemic indices together, WHR stands out as one of the most unique indices, as it doesn't measure mass but rather the risk associated with abdominal mass, which poses relatively higher risks to the impaired glucose uptake functions of an individual and, in turn, relatively higher risks to the onset of Type 2 diabetes mellitus. These criteria take special significance in an Asian mass where relatively higher risks are associated with impaired metabolism.[5–7]

Beyond adiposity, muscle strength has gained increasing recognition as an underestimated determinant of metabolic health. Handgrip strength (HGS), a widely used surrogate marker of overall muscle function, has been consistently associated with glucose metabolism and insulin sensitivity. A decline in HGS has been strongly linked to impairments in glucose uptake, mitochondrial dysfunction, and increased susceptibility to insulin resistance and type 2 diabetes. [8,9]

Diabetes mellitus remains a major global health challenge, characterized by chronic hyperglycemia due to impaired insulin secretion or action and leading to progressive metabolic and vascular complications, while its increasing prevalence and low rates of early detection, particularly in urban settings, highlight the need for practical community-based screening tools. Anthropometric indicators such as the waist-to-hip ratio (WHR) provide a simple measure of central adiposity, a key driver of insulin resistance, whereas handgrip strength (HGS) serves as a reliable proxy for muscle function and metabolic health, with lower HGS consistently associated with increased diabetes risk. Although WHR and HGS have been studied independently, evidence remains limited on their combined use in a unified, non-invasive predictive model, especially in Southeast Asian populations. Jakarta, as a rapidly urbanizing мeracity with high population density, lifestyle transitions, and a growing burden of metabolic disorders, represents a unique epidemiological context where such a model is particularly relevant. Therefore, this study aims to develop a predictive scoring model for diabetes among adults in Jakarta by integrating WHR and HGS, offering a cost-effective, field-applicable approach to early detection and preventive public health strategies.

METHOD

Study Design and Setting

This study employed an analytical observational design with a cross-sectional approach. The study was conducted from January 2024 to June 2025 across several districts in Jakarta, Indonesia, including Grogol, Tanjung Duren, Kota Bambu, Asisi Nursing Home, Cengkareng, and St. Joseph Church. The research was embedded within a series of community-based health screening programs organized to evaluate metabolic and anthropometric parameters among adults. All procedures were performed under standardized field protocols to ensure consistency, precision, and inter-observer reliability in data collection.

Population and Sampling

The study population consisted of adults aged 18 years and older who resided in urban and suburban areas of Jakarta. Five hundred thirty-nine participants were enrolled using a non-random consecutive sampling technique, in which all eligible individuals attending the health screening sessions during the study period participated. Inclusion criteria encompassed adults (≥18 years) who had fasted for at least eight hours before the examination, were physically capable of undergoing anthropometric measurements and handgrip strength assessment, and provided written informed consent. Participants were excluded if they had musculoskeletal or neurological disorders that could interfere with physical assessments or if they had incomplete anthropometric or biochemical data.

Procedure, Instrument, and Data Collection

The study participants were recruited in various districts in Jakarta. Before the study, each individual was explained in detail the goals and methods of the study, after which they gave written consent to participate. The data can be gathered by trained healthcare professionals in standardized clinical protocols to eliminate biases in data collection.

Each participant underwent anthropometric assessment, handgrip strength testing, and fasting blood glucose measurement. Anthropometric parameters included body weight, height, and multiple body circumferences (neck, arm, waist, hip, thigh, and calf), all measured using a standard non-elastic measuring tape to the nearest 0.1 cm. Waist-to-hip ratio (WHR) was calculated from the corresponding circumferences to represent central adiposity. Handgrip strength (HG) was assessed as an indicator of muscle function, while fasting blood glucose (FBG) levels were analyzed from venous blood samples collected after an overnight fast of at least eight hours. Each participant's examination took approximately 15–20 minutes, ensuring efficiency and data reliability across all study sites.

Statistical Analysis

The data analysis was done using IBM SPSS Statistics version 26.0. The study employed descriptive statistics, including mean, standard deviation, frequency, and percentage, to describe the characteristics of the study participants. Normality tests were conducted on the data using the Kolmogorov-Smirnov test for normality. The multiple linear regression model was employed to examine correlations between grip strength, WHR, and fasting blood glucose concentration after adjusting for age and gender. Binary logistic regression with a backward LR test was used to model the predictors of the risk of developing diabetes. The Hosmer-Lemeshow goodness-of-fit test assessed the model's calibration, while discriminant capability was evaluated using the receiver operating characteristic curve and the area under the curve (AUC). All tests were conducted two-tailed, with significance set at $p < 0.05$.

Ethical Clearance

The study was reviewed and approved by the Human Research Ethics Committee at Tarumanagara University under the Institute of Research and Community Engagement, Tarumanagara University (UTHREC), with ethical approval number 013-UTHREC/UNTAR/VI/2024. All study procedures were conducted in accordance with the ethical principles outlined in the Declaration of Helsinki for research involving human participants.

RESULT AND DISCUSSION

The Table 1 presents the demographic and anthropometric characteristics of the 539 participants in the study. The mean age was 52.08 ± 15.76 years (range: 18–96 years), with a predominance of female subjects (69.8%) compared to males (30.2%). The mean body weight and height were 64.29 ± 14.10 kg and 156.37 ± 8.32 cm, respectively, resulting in an average body mass index (BMI) of 26.26 ± 5.15 kg/m², indicating a tendency toward overweight status within the study population. Anthropometric parameters revealed a mean waist circumference of 89.55 ± 12.43 cm and a hip circumference of 99.25 ± 11.42 cm, resulting a waist-to-hip ratio (WHR) of 0.90 ± 0.09, indicating a relatively high central fat distribution. Meanwhile, the average handgrip strength was 23.15 ± 8.18 kg, reflecting interindividual variability in muscle function. Fasting blood glucose levels averaged 103.42 ± 45.01 mg/dL (range: 57–524 mg/dL), demonstrating substantial heterogeneity in metabolic profiles among participants.

Table 1. Characteristics of Research Results

Parameter	N (%)	Mean (SD)	Med (Min-Max)
Age (years)	539 (100)	52.08 (15.76)	52 (18 – 96)
Gender			
• Male	163 (30.2)		
• Female	376 (69.8)		
Body Weight (kg)		64.29 (14.10)	62.50 (28.90–130.40)
Height (cm)		156.37 (8.32)	155.10 (111.90–189.50)
Body Mass Index (kg/m²)		26.26 (5.15)	25.76 (12.53–46.64)
Waist Circumference (cm)		89.55 (12.43)	89.00 (53.00–133.50)
Hip Circumference (cm)		99.25 (11.42)	99.00 (47.00–148.00)
Neck Circumference (cm)		35.02 (3.97)	34.50 (22.50–48.30)
Waist-to-Hip Ratio (WHR)		0.90 (0.09)	0.90 (0.70–1.85)
Handgrip Strength (kg)		23.15 (8.18)	22.30 (5.20–60.60)
Fasting Blood Glucose (mg/dL)		103.42 (45.01)	91 (57 – 524)

The multiple linear regression analysis demonstrated that handgrip strength and waist–hip ratio (WHR) significantly influenced fasting blood glucose levels. At the same time, there was no meaningful association between body mass index (BMI) and neck circumference. Specifically, higher handgrip strength was inversely associated with fasting glucose (B = –0.606; β = –0.110; *p* = 0.021), indicating that greater muscular strength correlates with improved glycemic regulation, likely through enhanced insulin sensitivity and glucose utilization by skeletal muscles. Conversely, WHR exhibited a positive association (B = 58.629; β = 0.112; *p* = 0.019), indicating that central adiposity contributes to elevated fasting glucose through mechanisms involving visceral fat accumulation and insulin resistance. In the refined model, both WHR (B = –0.468; β = –0.085; *p* = 0.047) and handgrip strength (B = 72.647; β = 0.139; *p* = 0.001) remained significant predictors, reinforcing their independent and clinically relevant roles in glucose homeostasis. (Table 2)

The linear regression model generated in this study produced the following predictive equation:

$$\textbf{Fasting Blood Glucose Prediction} = \mathbf{48.652 - 0.468(HGS) + 72.647(WHR)}$$

Table 2. Multiple Linear Regression Anthropometry and Handgrip Strength on Fasting Blood Glucose

Parameter	Unstandardized Coefficient		Standardized Coefficient Beta	t	Sig
	B	Std. Error			
(Constant)	37.695	22.282		1.692	0.091
Handgrip Strength	-0.606	0.261	-0.110	-2.317	0.021
BMI	0.010	0.420	0.001	0.024	0.981
WHR	58.629	24.843	0.112	2.360	0.019
Neck Circumference	0.758	0.635	0.067	1.192	0.234
(Constant)	48.652	20.591		2.363	0.018
WHR	-0.468	0.235	-0.085	-1.990	0.047
Handgrip Strength	72.647	22.306	0.139	3.257	0.001

This equation demonstrates the relationship between handgrip strength (HGS), waist-to-hip ratio (WHR), and fasting blood glucose levels. The negative coefficient for HGS (-0.468) indicates that for every unit increase in handgrip strength, fasting blood glucose levels tend to decrease. This finding aligns with established physiological evidence that skeletal muscle mass and strength contribute significantly to glucose uptake and insulin-mediated metabolism. Stronger musculature reflects better metabolic fitness, which is associated with improved insulin sensitivity and glycemic control. Conversely, WHR exhibits a substantial positive coefficient (72.647), suggesting that increases in central adiposity are strongly associated with higher fasting blood glucose levels. This result is consistent with the pathophysiological mechanisms linking visceral adiposity to insulin resistance, chronic low-grade inflammation, and impaired glucose homeostasis. Overall, this predictive model suggests that a higher WHR, combined with reduced muscle strength, may serve as an indicator of elevated fasting blood glucose. These findings emphasize the clinical utility of simple, non-invasive screening tools such as handgrip dynamometry and WHR measurements for early identification of individuals at risk for metabolic dysregulation, enabling timely preventive and lifestyle-based interventions before progression to overt dysglycemia.

Furthermore, the binary logistic regression analysis, using the backward likelihood ratio (LR) method, identified sarcopenia and central obesity as significant predictors of diabetes among adults in Jakarta. The model demonstrated that individuals with sarcopenia had a significantly lower likelihood of developing diabetes (B = –0.867; p = 0.001; Exp(B) = 0.420), indicating that greater muscle mass and strength may exert a protective metabolic effect through enhanced insulin sensitivity and improved glucose utilization. Conversely, central obesity showed a strong positive association with diabetes risk (B = –2.413; p = 0.018; Exp(B) = 0.090), reflecting that excessive visceral fat accumulation markedly increases susceptibility to insulin resistance and impaired glucose metabolism. The high constant value (B = 4.535; p < 0.001; Exp(B) = 93.230) suggests a strong baseline probability of diabetes in the studied population when both sarcopenia and central obesity are absent. (Table 3)

This study supports the predictive value of simple anthropometric and functional measures, including the Waist-to-Hip Ratio (WHR) and handgrip strength (HG) in estimating glycemic status among adults in Jakarta. The findings demonstrate that WHR was positively associated with fasting blood glucose levels. At the same time, handgrip strength showed an inverse relationship, indicating that both central adiposity and muscle function play critical yet opposing roles in glucose homeostasis

Table 3. Binary Logistic Backward Likelihood Ratio WHR and Handgrip Strength on Diabetes in Jakarta

Parameter	B	S.E.	Wald	df	Sig.	Exp(B)
Sarcopenia	-0.867	0.260	11.111	1	0.001	0.420
Central Obesity	-2.413	1.018	5.623	1	0.018	0.090
Constant	4.535	1.018	19.841	1	0.000	93.230

The mean body mass index (26.26 ± 5.15 kg/m²) and WHR (0.90 ± 0.09) in this population suggest a general tendency toward overweight and central obesity, reflecting an urban metabolic profile commonly observed in Indonesian adults. This pattern aligns with regional epidemiological data, which show that urbanization, sedentary behavior, and dietary westernization have markedly increased the burden of obesity-related metabolic disorders. Central obesity, characterized by the excessive accumulation of visceral fat, plays a pivotal role in the pathogenesis of insulin resistance, dyslipidemia, and chronic low-grade inflammation, through the increased secretion of proinflammatory adipokines and reduced levels of adiponectin. [10,11]

The relatively low mean handgrip strength (23.15 ± 8.18 kg) observed in this cohort further underscores the growing prevalence of sarcopenic tendencies, even among middle-aged adults. From a physiological perspective, reduced muscle strength reflects not only quantitative loss of muscle mass but also qualitative impairments in muscle fiber composition and mitochondrial function, both of which may exacerbate insulin resistance by diminishing skeletal muscle glucose uptake and metabolic flexibility. [9,12,13]

This study demonstrated that WHR was positively and significantly associated with fasting glucose levels (B = 72.647; p = 0.001), indicating that central adiposity contributes substantially to glycemic dysregulation among adults. Visceral fat accumulation is metabolically active, secreting proinflammatory cytokines such as tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6), which disrupt insulin receptor signaling and promote hepatic glucose production, also known as gluconeogenesis. Moreover, the release of excess free fatty acids through heightened lipolytic activity induces hepatic steatosis and mitochondrial dysfunction, ultimately impairing insulin sensitivity. The logistic regression model further confirmed that elevated WHR independently increased the likelihood of diabetes (B = –2.413; Exp(B) = 0.090; p = 0.018), emphasizing that central obesity serves not merely as an anthropometric indicator but as a pathophysiological marker reflecting the adverse metabolic consequences of visceral adiposity. [14,15]

Evidence from recent studies emphasizes the role of central adiposity in diabetes risk. Aghaei et al. (2024) reported a higher prevalence of abnormal waist-to-hip ratio (WHR) among patients with diabetes, highlighting the strong association between central fat distribution and metabolic dysfunction.[16] Building on this, Baberi et al. (2025) found that WHR outperformed other anthropometric measures in predicting diabetes, with an optimal cutoff value of > 0.95 for both sexes. This restructured evidence reinforces WHR as a robust, simple, and clinically relevant indicator for identifying individuals at increased risk of diabetes. [17]

Conversely, HG exhibited a significant negative association with fasting glucose (B = –0.468; p = 0.047), underscoring the protective metabolic role of muscular fitness. Logistic regression reinforced this finding, demonstrating that low handgrip strength increased the odds of diabetes (B = –0.867; Exp(B) = 0.420; p = 0.001). Skeletal muscle, as the primary site of postprandial glucose disposal, mediates approximately 80% of insulin-stimulated glucose uptake through GLUT-4 translocation. [18,19]

Diminished muscle strength often reflects reduced muscle mass, intramyocellular lipid accumulation, and impaired mitochondrial oxidative capacity, all of which contribute to insulin resistance. Beyond its mechanical role, skeletal muscle acts as an endocrine organ, producing myokines such as irisin and myonectin, which enhance insulin sensitivity and lipid oxidation. Thus, handgrip strength serves as a functional and non-invasive surrogate for skeletal muscle integrity and metabolic resilience. [20–22]

Li et al. (2021) demonstrated that the inverse association between handgrip strength (HGS) and diabetes risk was consistent across gender, with stratified analyses showing a graded reduction in diabetes risk across increasing quartiles of both dominant and relative HGS in men and women. Age-stratified analyses further indicated that this protective association was evident across age groups, with a more pronounced effect among individuals younger than 60 years, and a significant interaction between relative HGS and age. These findings highlight reduced muscle strength as an independent risk factor for new-onset diabetes among middle-aged and older adults and suggest that relative HGS may have slightly superior predictive value. [23] Consistent with these observations, Lee et al. (2024) also reported that relative handgrip strength (RGS) can be used to identify individuals at high risk of diabetes who may benefit from early intervention, supporting the potential role of HGS-based screening as a practical strategy for diabetes prevention. [24]

The concomitant association between elevated WHR and diminished HG with increased diabetes risk provides robust empirical reinforcement for the “muscle–fat axis” hypothesis, which postulates that the interdependent dysregulation of adipose and skeletal muscle tissues underlies progressive metabolic dysfunction. Excess visceral adiposity contributes to systemic inflammation and ectopic lipid accumulation, thereby impairing insulin signaling pathways within skeletal muscle. Conversely, sarcopenia leads to a reduction in basal metabolic rate and glucose disposal capacity, further promoting adipose tissue expansion and metabolic inflexibility. This bidirectional pathophysiological interplay generates a self-reinforcing cycle of insulin resistance and chronic subclinical inflammation. Furthermore, adipose-derived proinflammatory cytokines, such as TNF-α and interleukin-1β (IL-1β), have been shown to suppress myogenic differentiation and enhance proteolytic activity, thereby accelerating muscle wasting. In turn, impaired muscle function augments lipid and hepatic gluconeogenesis, amplifying systemic metabolic derangement. [25–29]

From a translational perspective, integrating WHR and handgrip strength as dual predictors offers a simple yet physiologically grounded approach to early diabetes risk assessment in resource-limited or community-based settings. Both parameters are non-invasive, low-cost, and easily measurable, requiring no advanced laboratory infrastructure, making them ideal for primary prevention programs in urban populations, such as Jakarta. Incorporating these markers into routine health screenings could enhance early detection among individuals with subclinical insulin resistance, particularly within productive-age groups who are often asymptomatic yet metabolically vulnerable. Beyond screening, the model emphasizes the importance of multidimensional interventions that target both adiposity reduction and muscle strengthening through structured physical activity, resistance training, and nutritional optimization, aiming to restore metabolic balance. On a policy level, these findings support the development of locally contextualized diabetes prevention strategies that bridge clinical and community health domains, emphasizing functional fitness as an integral component of metabolic risk management in Indonesia's urban health landscape.

However, several limitations should be acknowledged. The analysis did not incorporate key potential confounding factors such as dietary intake, physical activity level, genetic predisposition, and socioeconomic conditions, all of which may independently affect metabolic status and muscle function. The cross-sectional design further limits causal interpretation, as temporal relationships between changes in central adiposity, muscle strength, and glycemic status cannot be established. In addition, data were obtained through single-point measurements during community-based screening, which may be influenced by intra-individual variability and measurement error, particularly in field settings where precision may be lower than in controlled laboratory environments. The use of non-random consecutive sampling also introduces the possibility of selection bias, potentially limiting the generalizability of the findings, while reliance on self-reported background information may contribute to recall bias. Collectively, these limitations underscore the need for future longitudinal studies with repeated measurements, more comprehensive lifestyle and biochemical data, and robust sampling strategies to strengthen causal inference and refine predictive models of diabetes risk.

CONCLUSION

This study successfully established a predictive model linking Waist-to-Hip Ratio (WHR) and handgrip strength (HG) to diabetes risk among adults in Jakarta. A significant positive association was observed between WHR and fasting glucose levels, indicating that central adiposity contributes to impaired glycemic regulation. By integrating these two parameters, the developed model offers a physiologically coherent and easily applicable tool for early diabetes risk stratification in community settings. Routine assessment of WHR and HG can help clinicians identify individuals at risk earlier, enabling targeted interventions such as weight management and strength-enhancing physical activity. This approach not only supports individualized preventive care but also aligns with broader public health strategies aimed at mitigating the growing diabetes burden in Indonesia's urban populations.

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