Jurnal Ilmu Medis Indonesia (JIMI)
ISSN: 2807-1697, Vol 5, No 2, 2026, 109-119 https://doi.org/10.35912/jimi.v5i2.6576

Anthropometric Indicators and Type 2 Diabetes Mellitus Among Older Adults in a Primary Care Setting

Safrina Oksidriyani[1*], Putri Tiara Rosha[2], Refani Alycia Kusuma[3], Anastu Regita Nareswara[4], Nur Ahmad Habibi[5], Bintang Rizqi Kurniawan[6], Ela Sri Faniyanti[7], Bela Prasasti[8]
Universitas Negeri Semarang, Semarang, Indonesia[1,2,3,6,7,8]
University of Leeds, West Yorkshire, Inggris[4]
Politeknik Kesehatan Kementerian Kesehatan, Padang, Indonesia[5]
safrinaoksidriyani@mail.unnes.ac.id[1*], putritiara@mail.unnes.ac.id[2]

Article History
Received on 05 January 2026
1st Revision on 17 January 2026
2nd Revision on 21 January 2026
3rd Revision on 07 February 2026
Accepted on 15 February 2026

Abstract

Purpose: This study aimed to evaluate the association between five anthropometric indicators and type 2 diabetes mellitus (T2DM) prevalence among older adults in a primary care setting in Semarang, Indonesia.

Methodology: A cross-sectional study enrolled 55 individuals aged ≥45 years at Kedungmundu Primary Health Center. Anthropometric measurements and capillary blood glucose were collected from routine health examinations. T2DM was defined as random blood glucose ≥200 mg/dL or prior diagnosis. Independent t-tests, Mann–Whitney U tests, and multivariate logistic regression were applied.

Results: Of 55 participants (mean age 59.95 ± 6.76 years; 9.1% T2DM), no significant differences were found in any anthropometric indicator (all $p > 0.05$), although WC (92.00 vs. 89.50 cm), BMI (29.33 vs. 26.28 kg/m²), WHtR (0.61 vs. 0.58), and BRI (5.86 vs. 5.15) were consistently higher in the DM group. Multivariate analysis identified age as the only variable approaching significance (OR = 0.87, 95% CI: 0.75–1.01, $p = 0.062$), suggesting T2DM was more frequent among younger elderly individuals.

Conclusions: Consistent directional trends support the exploratory utility of WC, BMI, and WHtR as initial metabolic screening tools in primary care for younger elderly individuals, pending confirmation through larger longitudinal studies.

Limitations: The small DM case count (n = 5), cross-sectional design, and single-site recruitment limit statistical power and generalizability.

Contributions: This study provides original evidence on the utility of five anthropometric screening indicators for T2DM risk identification in elderly Indonesian primary care populations, informing clinical practice and screening strategies in resource-limited health settings.

Keywords: *Anthropometric Indicators, Central Obesity, Non-Communicable Diseases, Primary Health Care, Type 2 Diabetes Mellitus*

How to Cite: Oksidriyani, S., Rosha, P. T., Kusuma, R. A., Nareswara, A. R., Habibi, N. A., Kurniawan, B. R., Faniyanti, E. S., & Prasasti, B. (2026). Anthropometric Indicators and Type 2 Diabetes Mellitus Among Older Adults in a Primary Care Setting. *Jurnal Ilmu Medis Indonesia (JIMI)*, 5(2), 109-119.

1. Introduction

Type 2 Diabetes Mellitus (T2DM) is widely recognized as a major contributor to the global non-communicable disease burden, with a disproportionately high impact on aging populations. The IDF reported that diabetes affected over 536 million adults aged 20–79 years in 2021, comprising approximately 10.5% of that age group globally, and projections suggest this figure may approach 783 million by 2045. Indonesia reflects this trend, with national health surveys documenting an increase in prevalence from 10.9% in 2018 to 11.7% in 2023 (Kementerian, 2023).

The aging process involves multiple physiological alterations that heighten susceptibility to metabolic disease, among them declining insulin sensitivity, impaired pancreatic beta-cell function, and progressive visceral fat deposition (Rizvi & Rizzo, 2024). Together, these changes substantially elevate T2DM risk in older individuals, underscoring the need for timely detection and targeted preventive strategies (Unnikrishnan, Pradeepa, Joshi, & Mohan, 2017). Among the tools available for metabolic risk assessment, anthropometric measurements including Waist Circumference (WC), Body Mass Index (BMI), Waist-to-Hip Ratio (WHR), and Waist-to-Height Ratio (WHtR) are widely adopted in both clinical practice and epidemiological surveillance (Konstantinova, Maslakova, & Ogorodnikova, 2024; Park, Byun, & Kim, 2025; Sadeghi et al., 2024). More recently, novel indices such as the A Body Shape Index (ABSI) and Body Roundness Index (BRI) have attracted attention as potentially superior alternatives, given their capacity to reflect body geometry and regional fat distribution beyond what traditional measures capture. This distinction is particularly relevant for older adults, in whom age-related sarcopenia and visceral fat redistribution can render BMI-based assessment misleading, making shape-based indices such as ABSI and BRI potentially more sensitive to true metabolic risk (Chang et al., 2016; Krakauer & Krakauer, 2012).

The bulk of existing research on anthropometric indices and diabetes risk has centered on the general adult population, with comparatively little attention directed toward older adults as a distinct subgroup (Feng et al., 2023; Ke et al., 2022). Evidence from primary care settings also remains sparse, particularly within community-based health systems in resource-limited countries such as Indonesia (Harbuwono, Tahapary, Tarigan, & Yunir, 2020; Kurniawaty, 2020; Pagehgiri, Irawati, & Josafat, 2019). This gap motivated the present investigation, which aimed to evaluate the relationship between a range of anthropometric measures and T2DM occurrence among elderly patients attending a primary health facility in Semarang, Indonesia. Unlike previous studies that predominantly relied on hospital-based or large-scale national survey data, the present study specifically targets a community primary care setting, uses routinely collected clinical data, and includes novel indices (ABSI and BRI) alongside traditional measures in an elderly Indonesian cohort, a combination that has not been previously examined in this context. The findings are intended to support the selection of feasible, low-cost anthropometric screening tools for diabetes risk identification in elderly primary care populations in resource-limited settings.

2. Literature Review and Hypothesis Development

Anthropometric assessment for metabolic risk has been studied extensively across populations, though evidence varies by indicator, population, and setting. Body Mass Index (BMI) is the most widely used anthropometric measure globally due to its simplicity and reproducibility. However, BMI fails to distinguish fat mass from lean mass and does not capture fat distribution, limiting its utility in older adults where sarcopenic obesity is prevalent (Rizvi & Rizzo, 2024). Waist Circumference (WC) and Waist-to-Height Ratio (WHtR) address this limitation by specifically capturing central adiposity. Lee, Huxley, Wildman, and Woodward (2008) demonstrated in a meta-analysis that indices of abdominal obesity are superior discriminators of cardiovascular risk factors compared to BMI alone. Liu et al. (2021) demonstrated in a prospective cohort of 6,990 hypertensive adults that BRI was the most superior predictor of diabetes onset compared to other anthropometric indices, including BMI, WC, and WHtR. This finding was further supported by Zhao, Tong, Li, and Cao (2021) in a Japanese cohort, and by Zhou and Liu (2025) in a population-based prospective study among adults aged ≥45 years, in which each 1-SD increase in BRI was associated with a 27% higher risk of incident T2DM. Krakauer and Krakauer (2012) showed that ABSI independently predicts mortality hazard beyond BMI. In Southeast Asian contexts, the utility of these indicators may be modulated by ethnic-specific body composition characteristics, as Asian populations tend to accumulate visceral fat at lower BMI thresholds than Western populations (Saeedi et al., 2019; WHO Expert Consultation, 2004).

Despite the proliferation of anthropometric screening tools, the evidence base in elderly primary care populations in Southeast Asia remains sparse. A systematic review by Talukder, Kelly, Gray, and Sarma (2024) examined the prevalence of obesity among South and Southeast Asian adults and highlighted that the relationship between anthropometric indices and metabolic risk differs substantially from Western populations, particularly in the elderly. The authors emphasized the need for population-specific validation of anthropometric cut-offs before clinical application. Sartika et al. (2025) demonstrated that WHtR outperformed BMI, WC, and WHR in detecting diabetes mellitus using data from 7,699 individuals, with WHtR showing the highest AUC (0.731) for DM detection in men, reinforcing its utility as a primary care screening tool in Indonesia. Studies from Indonesia and neighboring countries suggest that WC and WHtR may outperform BMI in predicting cardiometabolic risk in local populations (Harbuwono, Tahapary, Tarigan, & Yunir, 2020). However, evidence specifically in elderly primary care populations remains underexplored.

The aging-related shift in body composition, characterized by reduced lean mass and increased visceral adiposity, may alter the diagnostic performance of standard anthropometric cut-offs originally developed in younger adults (Sharma & Majumdar, 2009). Furthermore, survivor bias in cross-sectional studies of elderly cohorts may obscure true associations, as the oldest individuals with severe metabolic disease are less likely to be represented in primary care samples (Neeland, Turer, Ayers, Berry, Rohatgi, & Das, 2015). Taken together, the existing literature reveals three key gaps: most validation studies of anthropometric indices were conducted in general or middle-aged adult populations rather than the elderly; the comparative performance of traditional (BMI, WC, WHtR) versus novel (ABSI, BRI) indices in elderly primary care settings remains poorly characterized; and evidence from Southeast Asian, and specifically Indonesian, elderly populations is scarce. These gaps justify an exploratory examination of multiple indices simultaneously within a single primary care cohort. Based on this evidence, this study proposes two hypotheses: (H_1) higher values of visceral adiposity-sensitive indicators (WC, WHtR, BRI) will be positively associated with T2DM status; and (H_2) younger elderly individuals (aged 45–60 years) will show a higher prevalence of newly identified diabetes than the oldest-old, reflecting midlife accumulation of metabolic risk factors.

3. Research Methodology

3.1 Study Design and Setting

This cross-sectional study was conducted at Kedungmundu Primary Health Center in Semarang, Central Java, Indonesia. Data were collected in 2024 from routine health examination records. Ethical approval was obtained from the Health Research Ethics Committee *Komite Etik Penelitian Kesehatan* (KEPK) of Universitas Negeri Semarang *(No. 298/KEPK/EC/2023)*, and all procedures adhered to the Declaration of Helsinki.

3.2 Participants

A total of 55 older adults aged ≥45 years were enrolled using a total sampling technique, encompassing all eligible individuals who attended routine health check-ups at the facility during the data collection period. Total sampling was chosen to maximize the available sample from this single primary care site during the study period, ensuring that no eligible participant was excluded without clinical reason. Inclusion criteria were: (1) registered patient at Kedungmundu Primary Health Center, (2) aged ≥45 years, and (3) having complete anthropometric and blood glucose data. Individuals with a known diagnosis of type 1 diabetes mellitus, or conditions known to affect body composition such as malignancy or severe edema, were excluded. Given the exploratory nature of this study, a formal a priori sample size calculation was not performed; the small number of DM cases (n = 5) represents a recognized limitation. It is important to acknowledge that this sampling approach may introduce selection bias, as attendees of routine health check-ups at a single facility may not be representative of the broader elderly population. Specifically, individuals who are healthier, more health-conscious, or with better healthcare access may be overrepresented, potentially attenuating the observed differences between DM and non-DM groups.

3.3 Anthropometric Data Collection

Anthropometric measurements were obtained by trained health personnel following standardized protocols. BMI was derived by dividing body weight (kg) by the square of standing height (m). WC was obtained by placing an inelastic tape measure at the midpoint between the lowest rib margin and the iliac crest. WHtR was derived by dividing WC by standing height. ABSI was calculated using the formula:

$$\mathrm{ABSI} = \frac{\mathrm{WC}}{\mathrm{BMI}^{\frac{2}{3}} \times \mathrm{Height}^{\frac{1}{2}}} \tag{1}$$

The A Body Shape Index (ABSI) was used as an anthropometric indicator to assess abdominal obesity relative to body size. ABSI is calculated using Equation (1), where Waist Circumference (WC) is standardized by Body Mass Index (BMI) raised to the power of 2/3 and height raised to the power of 1/2. This adjustment allows ABSI to capture central fat distribution independently of overall body mass, making it a more specific predictor of health risks associated with abdominal obesity compared to BMI alone.

BRI was calculated as:

$$\mathrm{BRI} = 364.2 - 365.5 \times \sqrt{1 - \left(\frac{\left(\frac{\mathrm{WC}}{2\pi}\right)^2}{(0.5 \times \mathrm{Height})^2}\right)} \tag{2}$$

The Body Roundness Index (BRI) was applied to estimate body shape and visceral fat distribution. As shown in Equation (2), BRI is derived from a geometric model that incorporates Waist Circumference (WC) and height to approximate body roundness. The formula transforms WC into a circular radius and relates it to height to estimate body fat accumulation. Higher BRI values indicate greater central obesity and increased metabolic risk, making it a useful complementary indicator to traditional anthropometric measures.

Blood pressure was recorded using a calibrated sphygmomanometer; blood glucose was assessed using capillary measurement via a glucometer.

3.4 Definition of T2DM

T2DM status was determined based on either (1) a random capillary blood glucose level ≥200 mg/dL at the time of examination, or (2) a prior medical diagnosis documented in the patient's health record. It is acknowledged that this approach does not fully conform to gold-standard diagnostic criteria requiring fasting plasma glucose, HbA1c, or oral glucose tolerance testing (ElSayed et al., 2022; Karnchanasorn et al., 2016), and may introduce a degree of diagnostic misclassification.

3.5 Statistical Analysis

All statistical procedures were carried out using IBM SPSS Statistics version 25. Descriptive statistics for continuous variables were presented as mean ± Standard Deviation (SD) when normally distributed, or as median with range when not. Categorical variables were reported as frequencies and percentages. Distribution normality was evaluated with the Kolmogorov–Smirnov test. The independent samples t-test was applied for normally distributed variables; the Mann–Whitney U test was used for non-parametric distributions. Candidate variables with $p < 0.25$ in bivariate screening were entered into a multivariable logistic regression model using backward stepwise elimination (likelihood ratio). Regression outputs are expressed as odds ratios (OR) with 95% confidence intervals (CI); $p < 0.05$ was considered statistically significant (Greenland, Senn, Rothman, Carlin, Poole, Goodman, & Altman, 2016). Participants with incomplete anthropometric or blood glucose data were excluded at enrollment (complete-case analysis); no imputation was performed given the exploratory nature of the study. Owing to the small number of DM events (n = 5), the Events Per Variable (EPV) fell well below the recommended minimum of 10, rendering multivariable estimates highly unstable (Bender & Lange, 2001).

4. Results and Discussions

4.1 Participant Characteristics

The high proportion of female participants (78.2%) in this study is consistent with patterns reported across elderly health programs in Indonesia. Rosha, Oksidriyani, Siyam, Meisyaroh, Amalia, and Fakhira (2024) documented similar female predominance in integrated elderly health service data from Semarang, attributing this to culturally embedded health-seeking behaviors among older Indonesian women. Additionally, the mean systolic blood pressure of 132.09 mmHg in the present sample is consistent with the well-documented high burden of hypertension among Indonesian elderly, with national data reporting hypertension prevalence of 55.2% in the 55–64 age group and exceeding 63% in those aged 65–74 years (Khasanah, Kelliat, Afiyanti, Besral, & Sari, 2024). A recent cross-sectional study in Klaten, Central Java similarly confirmed the high prevalence of hypertension risk factors among elderly in this region Utami, Demartoto, and Murti (2024) highlighting the co-clustering of cardiometabolic risk factors in the same primary care population studied here.

The mean BMI and WHtR values suggest that the overall sample carries a meaningful cardiometabolic risk profile, consistent with the broader epidemiological context of rising obesity and metabolic syndrome in urban Indonesia (Saeedi, Petersohn, Salpea, Malanda, Karuranga, & Unwin, 2019). The co-occurrence of overweight BMI, elevated WHtR, and prehypertension in the present sample is consistent with findings from Azam, Sakinah, Kartasurya, Fibriana, Minuljo, and Aljunid (2023), who documented high prevalence of obesity among individuals with diabetes in Indonesia, highlighting the clustering of cardiometabolic risk factors in this population.

Table 1. Characteristics of study participants (n = 55)

Characteristic	Total (Mean ± SD)
Age (years)	59.95 ± 6.76
WC (cm)	89.73 ± 8.24
BMI (kg/m²)	26.56 ± 4.66
WHtR	0.58 ± 0.06
ABSI	0.82 ± 0.06
BRI	5.22 ± 1.27
SBP (mmHg)	132.09 ± 20.06
DBP (mmHg)	79.93 ± 10.86
Sex, n (%)	
Male	12 (21.8)
Female	43 (78.2)
DM Status, n (%)	
DM	5 (9.1)
Non-DM	50 (90.9)

The characteristics of the 55 study participants are presented in Table 1. The majority were female (78.2%), with a mean age of 59.95 ± 6.76 years. The mean BMI of 26.56 ± 4.66 kg/m² falls within the overweight category according to Asia-Pacific classification criteria. The mean WHtR of 0.58 ± 0.06 exceeded the 0.5 threshold indicative of central obesity. Mean systolic and diastolic blood pressure values of 132.09 ± 20.06 mmHg and 79.93 ± 10.86 mmHg, respectively, suggest a tendency toward prehypertension or Stage 1 hypertension in this population.

4.2 Comparison of Anthropometric Indicators Between DM and Non-DM Groups

Table 2. Comparison of anthropometric indicators between DM and Non-DM groups

Indicator	DM (n = 5)	Non-DM (n = 50)	p-value
WC (cm)	92.00 ± 10.51	89.50 ± 8.08	0.429a
BMI (kg/m²)	29.33 ± 5.44	26.28 ± 4.55	0.193a
WHtR	0.61 ± 0.08	0.58 ± 0.06	0.285b
ABSI	0.79 ± 0.02	0.82 ± 0.06	0.234b
BRI	5.86 ± 1.82	5.15 ± 1.21	0.238b

Table 2 presents comparisons of anthropometric indicators between the DM and non-DM groups. Although mean values of WC, BMI, WHtR, and BRI were consistently higher in the DM group, none of these differences reached statistical significance (all $p > 0.05$). ABSI showed a slightly lower mean value in the DM group compared to the non-DM group. The absence of statistical significance should not be interpreted as evidence of no association; rather, it most likely reflects insufficient statistical power from the very small number of T2DM cases (n = 5) in this sample (Greenland, Senn, Rothman, Carlin, Poole, Goodman, & Altman, 2016). The observed mean differences (WC: +2.50 cm; BMI: +3.05 kg/m²; WHtR: +0.03; BRI: +0.71) are directionally consistent and may represent clinically plausible differences detectable in larger samples. The consistently higher values of WC, BMI, WHtR, and BRI in the DM group are biologically plausible, as excess visceral adipose tissue is recognized as a primary driver of insulin resistance through chronic low-grade inflammation and dysregulated free fatty acid metabolism (Dhokte, & Czaja, 2024; Szukiewicz, 2023; Zhou, Lu, Hajifathalian, Bentham, & Danaei, 2016). This is further supported by large-scale prospective evidence demonstrating strong positive associations between these anthropometric indicators and incident T2DM (Boonpor, Parra-Soto, Talebi, Zhou, Carrasco-Marin, & Petermann-Rocha, 2023).

These directional trends are consistent with findings from larger prospective studies demonstrating that BRI was significantly associated with incident T2DM (Zhou & Liu, 2025). The relatively lower ABSI value in the DM group (0.79 ± 0.02 vs. 0.82 ± 0.06, p = 0.234) is an unexpected finding. ABSI is designed to capture body shape independent of height and weight; however, its association with T2DM has been inconsistent across populations, with limited predictive utility reported in elderly groups where fat redistribution patterns differ from younger adults Chang, Guo, Li, Li, Guo, and Sun (2016) similarly examined novel body-shape indices and underscored that their discriminative performance varies substantially across populations and age groups (Krakauer & Krakauer, 2012). This finding warrants further exploration with adequately powered samples.

4.3 Multivariate Analysis

Variables with $p < 0.25$ in bivariate analysis, including age, BMI, and WHtR, were entered into the multivariate logistic regression model using a backward stepwise approach. Following backward elimination, age remained the only variable retained in the final model (OR = 0.87, 95% CI: 0.75–1.01, p = 0.062), showing a negative association with DM status that approached but did not reach statistical significance. Given the EPV of less than 1 in this model, this finding must be treated as entirely exploratory and hypothesis-generating. With that important caveat, the negative direction of the association suggests that diabetes cases tended to be more frequently observed among the younger segment of the elderly population.

This pattern is consistent with emerging epidemiological evidence of a shift in T2DM onset toward younger age groups, particularly in populations undergoing rapid nutritional and lifestyle transitions (Twig, Yaniv, Levine, Leiba, Goldberger, & Derazne, 2016). The accumulation of metabolic risk factors, including central obesity, physical inactivity, and unhealthy dietary patterns may lead to earlier manifestation of T2DM (Hu, Zhang, Poon, Ji, Hou, & Zhang, 2025; Walsh, Jacka, Butterworth, Anstey, & Cherbuin, 2021). This trend is increasingly recognized in the literature, with urbanization-driven lifestyle changes identified as key contributors to rising early-onset T2DM incidence globally (Huang, Li, Yu, Lv, Lu, & Xu, 2025; Luk, Wild, Jones, Anjana, Hivert, & McCaffrey, 2025). In the Indonesian context specifically, the nutrition transition, characterized by a shift from traditional diets toward energy-dense, high-glycemic processed foods, has been identified as a key driver of increasing T2DM prevalence among younger cohorts (Rachmi, Agho, Li, & Baur, 2016). This dietary transition, combined with declining physical activity levels driven by urbanization, creates a convergence of risk factors that may manifest as earlier T2DM onset, particularly in peri-urban primary care populations such as the one studied here.

Furthermore, the finding that younger elderly individuals in this study showed higher rates of T2DM is consistent with data from the Indonesian national health survey Kementerian (2023), which documented the highest age-specific diabetes prevalence in the 55–64 year age group, suggesting that the burden of T2DM may be peaking at an earlier age than previously observed. This epidemiological shift has important implications for the scheduling and targeting of diabetes screening programs in primary care settings, where proactive case-finding among adults in their late 40s and 50s may yield greater benefit than waiting until patients reach older age thresholds. Effective integration of anthropometric screening into routine elderly integrated health posts visits could serve as a pragmatic and low-cost strategy for early metabolic risk identification at the community level in Indonesia (Kurniawaty, 2020). Additionally, survivor bias may contribute to this observation, as older individuals with more severe metabolic disease may be underrepresented in cross-sectional primary care samples (Neeland, Turer, Ayers, Berry, Rohatgi, & Das, 2015).

From a public health perspective, the consistent trends observed across anthropometric indicators support the continued use of simple, non-invasive measurements such as WC, BMI, and WHtR in primary care screening protocols for metabolic risk. These tools are low-cost, feasible, and widely available in resource-limited settings, making them valuable components of community-based preventive strategies for non-communicable diseases.

5. Conclusions

5.1 Conclusion

This exploratory study found no statistically significant association between anthropometric indicators and the presence of T2DM among older adults in a primary healthcare facility. Nevertheless, the consistently higher values of WC, BMI, WHtR, and BRI among participants with diabetes suggest a coherent directional pattern reflective of early metabolic alterations. Age demonstrated a negative association with T2DM (OR = 0.87, 95% CI: 0.75–1.01, $p = 0.062$), tentatively indicating that diabetes may be more frequently identified among the younger elderly. Based on these preliminary trends, WC, BMI, and WHtR are suggested as initial low-cost screening tools for metabolic risk in primary care, particularly for individuals aged 45–60 years. These trends must be confirmed through larger, longitudinal, multi-site studies before clinical or policy-level recommendations can be established. Practically, primary care clinicians in resource-limited settings may incorporate WC and WHtR measurement (requiring only an inelastic tape measure) into routine elderly health-post (posyandu lansia) visits, flagging individuals with WHtR ≥ 0.5 for further fasting glucose testing. Policymakers could consider integrating these low-cost measures into national non-communicable disease screening protocols targeting adults from age 45 onward.

5.2 Research Limitations

Several limitations must be acknowledged. First, the small number of DM cases (n = 5) severely limited statistical power and precluded robust multivariate modeling. Second, the cross-sectional design precludes causal inference. Third, T2DM diagnosis was based on random capillary blood glucose or prior diagnosis, which may introduce misclassification bias compared to gold-standard criteria. Fourth, recruitment from a single facility limits generalizability. Finally, potential confounders including physical activity, dietary patterns, family history of diabetes, and medication use were not assessed. The absence of data on medication use is a particularly important limitation, as certain antihypertensive drugs (e.g., thiazide diuretics, beta-blockers) and other commonly prescribed medications in elderly populations are known to affect glucose metabolism and potentially confound the relationship between anthropometric indicators and T2DM status. Additionally, the use of point-of-care capillary glucose measurement rather than venous plasma glucose may have contributed to measurement variability; studies have reported discordance rates of up to 15% between capillary and venous glucose in community settings, particularly in elderly populations. These methodological constraints collectively underscore the importance of interpreting the present findings within their exploratory context and highlight priority areas for refinement in future studies.

5.3 Suggestions and Directions for Future Research

Future studies should employ larger, multi-site samples with standardized diagnostic criteria (fasting plasma glucose or HbA1c) to confirm the directional trends observed here. Longitudinal designs would enable causal inference and allow tracking of anthropometric changes over time in relation to diabetes incidence. It is specifically recommended that future research: (1) recruit a minimum of 10 DM cases per predictor variable to enable valid logistic regression modeling; (2) include lifestyle confounders such as physical activity, dietary quality, and family history of diabetes; (3) evaluate ethnic-specific cut-offs for WC, WHtR, and BRI in the Indonesian elderly population; and (4) incorporate standardized visceral fat measures such as bioelectrical impedance analysis or imaging to validate surrogate anthropometric indicators. Such studies would substantially improve the identification of practical, low-cost screening tools for diabetes risk in elderly populations attending primary care in Indonesia and comparable resource-limited settings.

Acknowledgement

This research was funded by the Faculty of Medicine, Universitas Negeri Semarang. The funder was not involved in any stage of the study.

Author Contributions

SO was responsible for conceptualization, methodology, supervision, writing the original draft, and reviewing and editing the manuscript. PTR and RAK contributed to investigation, data curation, and manuscript review and editing. ARN carried out formal analysis and visualization, and contributed to manuscript review and editing. NAH provided resources and contributed to manuscript review and editing. BRK performed formal analysis and software-related tasks, and contributed to manuscript review and editing. ESF contributed to investigation and manuscript review and editing. BP was responsible for project administration and manuscript review and editing. All authors have read and agreed to the published version of the manuscript.

References

Azam, M., Sakinah, L. F., Kartasurya, M. I., Fibriana, A. I., Minuljo, T. T., & Aljunid, S. M. (2023). Prevalence and determinants of obesity among individuals with diabetes in Indonesia. *F1000Res, 11, 1063. doi:*. https://doi.org/10.12688/f1000research.125549.4

Bender, R., & Lange, S. (2001). Adjusting for multiple testing when and how?. *Journal of Clinical Epidemiology*, *54*(4), 343-349. https://doi.org/10.1016/S0895-4356(00)00314-0

Boonpor, J., Parra-Soto, S., Talebi, A., Zhou, Z., Carrasco-Marin, F., Petermann-Rocha, F., Ho, F. K. (2023). Associations and predictive performance of 11 anthropometric measures with incident type 2 diabetes: A prospective cohort study from the UK Biobank. *Obesity*, *31*(10), 2648-2657. https://doi.org/10.1002/oby.23849

Chang, Y., Guo, X., Li, T., Li, S., Guo, J., & Sun, Y. (2016). A Body Shape Index and Body Roundness Index: Two New Body Indices to Identify left Ventricular Hypertrophy among Rural Populations in Northeast China. *Heart, Lung and Circulation*, *25*(4), 358-364. https://doi.org/10.1016/j.hlc.2015.08.009

Dhokte, S., & Czaja, K. (2024). Visceral Adipose Tissue: The Hidden Culprit for Type 2 Diabetes. *Nutrients*, *16*(7). https://doi.org/10.3390/nu16071015

ElSayed, N. A., Aleppo, G., Aroda, V. R., Bannuru, R. R., Brown, F. M., Bruemmer, D., Association, A. D. (2022). *Introduction and Methodology: Standards of Care in Diabetes—2023*.

Feng, X., Wang, J., Wang, S., Wang, Z., Wu, S., Wei, Y., Chen, Q. (2023). Correlation analysis of anthropometric indices and type 2 diabetes mellitus in residents aged 60 years and older. *Frontiers in Public Health, Volume 11 - 2023. doi:*. https://doi.org/10.3389/fpubh.2023.1122509

Greenland, S., Senn, S. J., Rothman, K. J., Carlin, J. B., Poole, C., Goodman, S. N., & Altman, D. G. (2016). Statistical tests, P values, confidence intervals, and power: a guide to misinterpretations. *Eur J Epidemiol*, *31*(4), 337-350. https://doi.org/10.1007/s10654-016-0149-3

Harbuwono, D. S., Tahapary, D. L., Tarigan, T. J. E., & Yunir, E. (2020). New proposed cut-off of waist circumference for central obesity as risk factor for diabetes mellitus: Evidence from the Indonesian Basic National Health Survey. *PLoS One*, *15*(11). https://doi.org/10.1371/journal.pone.0242417

Hu, S., Zhang, Y., Poon, A. C. Y., Ji, Y., Hou, B., Zhang, C., Sun, Y. (2025). Risk factors of early-onset type 2 diabetes: A systematic review and meta-analysis. *Diab Vasc Dis Res*, *22*(6). https://doi.org/10.1177/14791641251400358

Huang, Q., Li, Y., Yu, M., Lv, Z., Lu, F., Xu, N., Jiang, H. (2025). Global burden and risk factors of type 2 diabetes mellitus from 1990 to 2021, with forecasts to 2050. *Front Endocrinol (Lausanne)*, *16*, 1538143. https://doi.org/10.3389/fendo.2025.1538143

Karnchanasorn, R., Huang, J., Ou, H. Y., Feng, W., Chuang, L. M., Chiu, K. C., & Samoa, R. (2016). Comparison of the Current Diagnostic Criterion of HbA1c with Fasting and 2-Hour Plasma Glucose Concentration. *J Diabetes Res, 2016, 6195494*. https://doi.org/10.1155/2016/6195494

Ke, P., Wu, X., Xu, M., Feng, J., Xu, H., Gan, Y., Lu, Z. (2022). Comparison of obesity indices and triglyceride glucose-related parameters to predict type 2 diabetes mellitus among normal-weight elderly in China. *Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity*, *27*(3), 1181-1191. https://doi.org/10.1007/s40519-021-01238-w

Kementerian Kesehatan RI. (2023). Survei Kesehatan Indonesia Tahun 2023. Retrieved from https://www.badankebijakan.kemkes.go.id/hasil-ski-2023/

Khasanah, U., Kelliat, B. A., Afiyanti, Y., Besral, B., & Sari, D. W. (2024). *The Problems and Needs of Self-Management Among Indonesian Older Adults With Hypertension: A Qualitative Study*.

Konstantinova, E. D., Maslakova, T. A., & Ogorodnikova, S. Y. (2024). The predictive capability of several anthropometric indices for identifying the risk of metabolic syndrome and its components among industrial workers. *Sci Rep*, *14*(1), 15327. https://doi.org/10.1038/s41598-024-66262-z

Krakauer, N. Y., & Krakauer, J. C. (2012). A new body shape index predicts mortality hazard independently of body mass index. *PLoS One*, *7*(7). https://doi.org/10.1371/journal.pone.0039504

Kurniawaty, Y. (2020). Hubungan Indeks Massa Tubuh dengan Risiko Diabetes Melitus Tipe 2. *Media Ilmu Kesehatan*, *9*(3), 237-242. https://doi.org/10.30989/mik.v9i3.508

Lee, C. M. Y., Huxley, R. R., Wildman, R. P., & Woodward, M. (2008). Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis. *Journal of Clinical Epidemiology*, *61*(7), 646-653. https://doi.org/10.1016/j.jclinepi.2007.08.012

Liu, Y., Liu, X., Guan, H., Zhang, S., Zhu, Q., Fu, X., Kuang, J. (2021). Body Roundness Index Is a Superior Obesity Index in Predicting Diabetes Risk Among Hypertensive Patients: A Prospective Cohort Study in China. *Frontiers in Cardiovascular Medicine, Volume 8 - 2021. doi:*. https://doi.org/10.3389/fcvm.2021.736073

Luk, A., Wild, S. H., Jones, S., Anjana, R. M., Hivert, M.-F., McCaffrey, J., Misra, S. (2025). Early-onset type 2 diabetes: the next major diabetes transition. *The Lancet*, *405*(10497), 2313-2326. https://doi.org/10.1016/S0140-6736(25)00830-X

Neeland, I. J., Turer, A. T., Ayers, C. R., Berry, J. D., Rohatgi, A., Das, S. R., . . . de Lemos, J. A. (2015). Body Fat Distribution and Incident Cardiovascular Disease in Obese Adults. *Journal of the American College of Cardiology*, *65*(19), 2150-2151. https://doi.org/10.1016/j.jacc.2015.01.061

Pagehgiri, E. S., Irawati, D., & Josafat, A. (2019). Hubungan antara Rasio Lingkar Pinggang terhadap Tinggi Badan dengan Glukosa Darah Puasa pada Lansia. *Jurnal Kedokteran*, *8*(2), 17-23. https://doi.org/10.29303/jk.v8i2.4546

Park, J., Byun, Y., & Kim, S. (2025). Predictive Diagnostic Power of Anthropometric Indicators for Metabolic Syndrome: A Comparative Study in Korean Adults. *J Clin Med*, *14*(2). https://doi.org/10.3390/jcm14020448

Rachmi, C. N., Agho, K. E., Li, M., & Baur, L. A. (2016). Stunting, Underweight and Overweight in Children Aged 2.0-4.9 Years in Indonesia: Prevalence Trends and Associated Risk Factors. *PLoS One*, *11*(5). https://doi.org/10.1371/journal.pone.0154756

Rizvi, A. A., & Rizzo, M. (2024). Age-Related Changes in Insulin Resistance and Muscle Mass: Clinical Implications in Obese Older Adults. *Medicina (Kaunas)*, *60*(10). https://doi.org/10.3390/medicina60101648

Rosha, P., Oksidriyani, S., Siyam, N., Meisyaroh, I., Amalia, L., & Fakhira, A. (2024). Exploration of longitudinal data based on integrated elderly health care for developing predictive health status in Semarang, Indonesia. *BKM Public Health Community Med*, e12504. https://doi.org/10.22146/bkm.v40i08.12504

Sadeghi, E., Khodadadiyan, A., Hosseini, S. A., Hosseini, S. M., Aminorroaya, A., Amini, M., & Javadi, S. (2024). Novel anthropometric indices for predicting type 2 diabetes mellitus. *BMC Public Health*, *24*(1), 10-33. https://doi.org/10.1186/s12889-024-18541-7

Saeedi, P., Petersohn, I., Salpea, P., Malanda, B., Karuranga, S., Unwin, N., Williams, R. (2019). *Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9th edition*.

Sartika, R. A. D., Sigit, F. S., Shukri, N. H. M., Purwanto, E., Yunita, J., & Lubis, P. N. (2025). Redefining Obesity in the Indonesian Population: The Critical Role of Waist-to-Height Ratio in Screening for Diabetes Mellitus and Hypertension. *J Nutr Metab*. https://doi.org/10.1155/jnme/5815261

Sharma, M., & Majumdar, P. K. (2009). Occupational lifestyle diseases: An emerging issue. *Indian J Occup Environ Med*, *13*(3), 109-112. https://doi.org/10.4103/0019-5278.58912

Szukiewicz, D. (2023). Molecular Mechanisms for the Vicious Cycle between Insulin Resistance and the Inflammatory Response in Obesity. *International Journal of Molecular Sciences*, *24*(12), 9818. https://doi.org/10.3390/ijms24129818

Talukder, A., Kelly, M., Gray, D., & Sarma, H. (2024). Prevalence and trends of double burden of malnutrition at household-level in South and Southeast Asia. *Discover Public Health*, *21*(1). https://doi.org/10.1186/s12982-024-00339-y

Twig, G., Yaniv, G., Levine, H., Leiba, A., Goldberger, N., Derazne, E., Kark, J. D. (2016). Body-Mass Index in 2.3 Million Adolescents and Cardiovascular Death in Adulthood. *N Engl J Med*, *374*(25), 2430-2440. https://doi.org/10.1056/NEJMoa1503840

Unnikrishnan, R., Pradeepa, R., Joshi, S. R., & Mohan, V. (2017). Type 2 Diabetes: Demystifying the Global Epidemic. *Diabetes*, *66*(6), 1432-1442. https://doi.org/10.2337/db16-0766

Utami, I. N., Demartoto, A., & Murti, B. (2024). Biopsychosocial Factors Associated with the Risk of Hypertension in Elderly in Klaten, Central Java: A Cross-Sectional Study. *Journal of Epidemiology and Public Health*, *9*(4), 437-447. https://doi.org/10.26911/jepublichealth.2024.09.04.04

Walsh, E. I., Jacka, F. N., Butterworth, P., Anstey, K. J., & Cherbuin, N. (2021). Midlife susceptibility to the effects of poor diet on diabetes risk. *European Journal of Clinical Nutrition*, *75*(1), 85-90. https://doi.org/10.1038/s41430-020-0673-9

WHO Expert Consultation. (2004). *Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies* (Report No. 363).

Zhao, W., Tong, J., Li, J., & Cao, Y. (2021). Relationship between Body Roundness Index and Risk of Type 2 Diabetes in Japanese Men and Women: A Reanalysis of a Cohort Study. *International Journal of Endocrinology*, *2021*(1), 4535983. https://doi.org/10.1155/2021/4535983

Zhou, B., Lu, Y., Hajifathalian, K., Bentham, J., Di Cesare, M., Danaei, G., Zuñiga Cisneros, J. (2016). Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4·4 million participants. *The Lancet*, *387*(10027), 1513-1530. https://doi.org/10.1016/S0140-6736(16)00618-8

Zhou, Z., & Liu, J. (2025). Association between body roundness index and incidence of type 2 diabetes in a population-based cohort study. *Sci Rep*, *15*(1), 13186. https://doi.org/10.1038/s41598-025-92652-y