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Association of HbA1c levels with anthropometric measures and body composition: Emphasis on waist-to-hip ratio as a marker of glycemic impairment

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ABSTRACT

Objective: This study aimed to evaluate the relationships between glycated hemoglobin (HbA1c) levels and anthropometric measurements (body mass index (BMI), waist circumference (WC), and waist-to-hip ratio (WHR) as well as body composition parameters.

Method: A total of 145 individuals (control, n=49; prediabetes, n=48; type 2 diabetes, n=48) were included in this cross-sectional study. HbA1c levels, BMI, WC, and WHR were measured in the participants; body composition was assessed using bioelectrical impedance analysis (BIA). Appropriate parametric and non-parametric tests were used for between-group comparisons, and relationships among variables were examined using correlation analyses. Analyses adjusted for age, gender, use of antidiabetic medications, and regular physical activity status were performed using generalized linear models (GLM).

Results: BMI, WC, and WHR values were found to be significantly lower in the control group compared to the prediabetes (preDM) and type 2 diabetes (T2DM) groups ($p<0.001$). No significant difference was observed between the preDM and T2DM groups regarding these parameters. Body fat percentage and fat mass were found to be higher in the preDM and T2DM groups compared to the control group ($p<0.001$). HbA1c levels showed a positive correlation with BMI, WC, WHR, body fat percentage, and fat mass ($p<0.05$). In analyses adjusted for gender and age, WC and WHR were found to be independently associated with HbA1c, with the strongest association observed for WHR (β: 4.301; $p=0.006$).

Conclusion: In this study, abdominal obesity indicators, particularly WC and WHR, showed stronger associations with HbA1c levels compared to BMI. These findings suggest that markers of abdominal obesity may be associated with glycemic status. However, due to the cross-sectional study design, these associations cannot be interpreted as causal.

Keywords: HbA1c, waist circumference, waist-to-hip ratio, type 2 diabetes, prediabetes

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Introduction

Diabetes mellitus (DM) has become a major public health problem due to its increasing prevalence and the serious complications it causes.[1] Type 2 diabetes mellitus (T2DM) accounts for the majority of diabetes cases and is closely associated with obesity. In particular, abdominal fat accumulation and increased body fat percentage play a significant role in insulin resistance and impaired glycemic control.[2,3]

Although body mass index (BMI) is widely used in the assessment of obesity, it has limitations as it does not reflect body fat distribution.[4] In contrast, waist circumference (WC) and waist-to-hip ratio (WHR) are indicators that better reflect abdominal adiposity and may show stronger associations with diabetes risk.[5,6]

Bioelectrical impedance analysis (BIA) is a commonly used non-invasive method for assessing body composition and allows a more detailed evaluation of parameters such as fat mass and fat-free mass.[7] It is known that changes in body composition affect glucose metabolism and insulin sensitivity.[8,9]

HbA1c is a reliable biomarker reflecting average blood glucose levels over the past 2–3 months and is widely used for long-term glycemic control assessment.[10] However, the strength and relative importance of the relationships between HbA1c and various obesity indicators and body composition parameters are not yet fully clear.

The aim of this study is to comparatively evaluate the relationships between HbA1c levels and anthropometric measurements (BMI, WC, and WHR) as well as body composition parameters determined by BIA in healthy individuals and those diagnosed with preDM and T2DM, and to elucidate the role of abdominal obesity indicators in particular. However, studies that evaluate these parameters comparatively within the same population and in conjunction with multivariate analyses are limited.

Main Points

- Indicators reflecting abdominal obesity (WC and WHR) show stronger associations with HbA1c levels compared to BMI.
- These findings suggest that considering WC and, particularly, WHR measurements may be beneficial in assessing glycemic status.
- The observed associations between HbA1c, anthropometric measurements, and body composition parameters in the prediabetes stage support the notion that metabolic impairment begins early.

Materials and Methods

Study population and design

This study was designed as a cross-sectional study. A total of 145 individuals aged between 19 and 65 years who presented to the Internal Medicine Outpatient Clinic, Ankara Bilkent City Hospital between November 2024 and June 2025 were consecutively included, provided that biochemical blood test results obtained within the previous 48 hours were available. The sample size of the study was determined prior to data collection using an a priori power analysis via G*Power software (version 3.1.9.7). Assuming an effect size of f = 0.40, a significance level of $\alpha = 0.05$, and a statistical power of 95% ($1-\beta = 0.95$), the minimum required sample size was calculated as 102 participants. A total of 145 participants were included in the study.

Participants were categorized into three groups according to their clinical diagnoses:

1. Control group: individuals with HbA1c < 5.7% and no comorbidities,
2. PreDM group: individuals with fasting plasma glucose (PG) 100–125 mg/dL and a 2-hour PG result of 140–199 mg/dL on an oral glucose tolerance test (OGTT) (75 g glucose) and/or HbA1c 5.7–6.4%,
3. T2DM group; individuals meeting any of the following criteria: fasting PG ≥126 mg/dL after at least 8 hours of fasting, or 2-hour PG ≥200 mg/dL on an OGTT (75 g glucose), or random PG ≥200 mg/dL, or HbA1c ≥6.5%, in the presence of typical DM symptoms.[2]

Individuals under 19 years of age and over 65 years of age, those unable to provide informed consent, insulin users, those with type 1 DM, gestational DM, malignancy, severe systemic disease (heart failure, liver or kidney disease, or lung disease, etc.), those with a history of psychiatric or neurological disorders, individuals with severe acute or chronic infectious diseases, and pregnant or breastfeeding women were excluded from the study.

Ethical approval for the study was obtained from the Ankara Bilkent City Hospital Scientific and Ethical Review

Board for Medical Research (TABED) on October 2, 2024, under number TABED 2 – 24 – 553.

Data collection

Data were collected using a face-to-face questionnaire. Body weight, height, waist circumference, and hip circumference were measured using standard methods, and BMI was calculated. Body weight and composition (body fat percentage, muscle mass) were measured using a BIA device. Waist circumference was measured at the midpoint between the lowest rib and the iliac crest using a measuring tape, while hip circumference was measured at the widest part of the hips.[11]WHR was calculated as waist circumference divided by hip circumference and was analyzed as a continuous variable in the statistical analyses.

Biochemical parameters were obtained from routine laboratory analyses ordered by a physician at the hospital and analyzed at the Medical Biochemistry Laboratory of Ankara Bilkent City Hospital.

Physical activity status was assessed in accordance with the international guidelines recommending at least 150 minutes of moderate-intensity exercise per week for individuals with diabetes. Participants were questioned about their regular exercise habits, including the type (e.g., walking, running, swimming, pilates), duration, and weekly frequency of the activities. Participants who met the 150-minute threshold were categorized as 'regularly exercising', while those who did not were categorized as 'not regularly exercising'.[12]

Statistical analysis

The normality of the data obtained in the study was assessed using the Kolmogorov-Smirnov test. Continuous variables are presented as mean ± standard deviation (mean ± SD) or median (interquartile range [IQR]), as appropriate.

For comparisons between groups, one-way analysis of variance (ANOVA), the Kruskal-Wallis test, and the Mann-Whitney U test were used as appropriate. Bonferroni-adjusted post-hoc tests were applied for significant results. Categorical variables were analyzed using the chi-square test.

The relationship between HbA1c groups and anthropometric measurements and body composition parameters was examined using Spearman's correlation analysis. Analyses adjusted for gender, regular physical activity status, and antidiabetic medication use were performed using one-way analysis of covariance (ANCOVA). The independent relationships between HbA1c levels and the variables were determined using a general linear model (GLM) adjusted for gender and age. Because anthropometric variables were expressed on different numerical scales, interpretation of β coefficients was performed cautiously and focused primarily on the direction and statistical significance of associations rather than direct comparison of coefficient magnitudes. To minimize potential multicollinearity, anthropometric and body composition variables were evaluated in separate regression models. Multicollinearity was assessed using variance inflation factor (VIF), and all observed values remained within acceptable limits.

Statistical significance was accepted as $p<0.05$.[13]

The analyses were conducted using three different approaches.

1. control, preDM, and T2DM groups formed based on clinical diagnosis,
2. groups based on HbA1c levels (<5.7; 5.7–6.4; ≥6.5) to evaluate relationships independent of diagnosis,
3. correlation and covariance analyses based on HbA1c values.

In HbA1c-based analyses, the use of antidiabetic medications and regular physical activity were taken into account. The statistical tests used for each analysis are specified below the relevant tables.

Results

Demographic characteristics and HbA1c levels

A total of 145 participants (control: n=49, preDM: n=48, T2DM: n=48) were included in the study. A significant difference in age was observed between the groups ($p=0.015$); the control group was found to be younger than the preDM and T2DM groups ($p<0.05$), while no difference was observed between the preDM and T2DM groups ($p>0.05$). No difference was found in gender distribution among the groups ($p=0.081$). HbA1c levels showed significant differences among the groups ($p<0.001$), and all groups were found to be significantly different from one another ($p<0.05$).

The demographic characteristics and HbA1c levels are presented in Table 1.

Comparison of anthropometric measurements across groups

BMI, WC, and WHR values showed significant differences across groups (p<0.001 for all results). These parameters were found to be lower in the control group compared to the preDM and T2DM groups; however, no significant difference was observed between the preDM and T2DM groups.

In the analysis by gender, no significant effect was observed on BMI (p>0.05), while WC and WHR values were found to be higher in males (p<0.001).

The results of the anthropometric measurements are presented in Table 2.

Distribution of body composition parameters across groups

Body fat percentage and fat mass showed significant differences across groups (p<0.001), and these values were lower in the control group. No significant difference was observed between the PreDM and T2DM groups. No significant difference was observed between the groups in terms of FFM (p=0.09). When evaluated by gender, body fat percentage and fat mass were higher in females, while FFM was higher in males (p<0.05).

The results are presented in Table 3.

Table 1. Demographic characteristics and HbA1c levels

Variable	Control (n= 49)	PreDM (n= 48)	T2DM (n= 48)	p-value
Age (years)	41 (36-46)a	46 (41-52)b	44 (40-49)b	0.015
HbA1c (%)	5.3 (5.1-5.5)a	5.9 (5.8-6.1)b	7.6 (6.4-8.9)c	<0.001
Gender (M/F)	17/32	19/29	27/21	0.081

Data are given as median (IQR). Kruskal-Wallis test with Bonferroni post-hoc analysis was used. Different superscripts (a, b, c) indicate significant differences between groups. p<0.05 was considered statistically significant.
HbA1c: glycated hemoglobin; DM: diabetes mellitus; T2DM: type 2 diabetes mellitus; M: male; F: female.

Table 2. Distribution of anthropometric measurements across groups

Variable	Control (n= 49)	PreDM (n= 48)	T2DM (n= 48)	p-value	Gender Effect
BMI	26.7 ± 4.7a	32.3 ± 5.8b	31.9 ± 4.4 b	<0.001	Not Significant
WC	92.4 ± 13.6a	103.6 ± 12.1b	106.1 ± 9.9b	<0.001	Male> Female*
WHR	0.87 ± 0.1a	0.94 ± 0.09b	0.96 ± 0.06b	<0.001	Male> Female*

Data are given as mean ± SD. ANOVA was applied for comparisons. Different superscripts (a, b) indicate significant differences between groups.
p<0.05 was considered statistically significant. *p<0.001
BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio; DM: diabetes mellitus; T2DM: type 2 diabetes mellitus.

Table 3. Distribution of body composition parameters across group

Variable	Control (n= 49)	PreDM (n= 48)	T2DM (n= 48)	p-value	Gender Effect
Body fat (%)	27.0 (22.5-31.5)a	36.7 (29.0-44.2)b	32.0 (26.5-37.5)b	<0.001	Female> Male*
Fat mass (kg)	21.0 (15.5-26.5)a	29.7 (20.3-39.0)b	28.6 (22.8-34.5)b	<0.001	Female> Male*
FFM	51.7 (42.7-60.7)	53.4 (44.7-61.0)	58.7 (49.4-68.0)	0.09	Male> Female*

Data are given as median (IQR). Kruskal-Wallis test with Bonferroni post-hoc analysis was used. Gender differences were analyzed using the Mann-Whitney U test. Different superscripts (a, b) indicate significant differences between groups. p<0.05 was considered statistically significant. * p<0.05
DM: diabetes mellitus; T2DM: type 2 diabetes mellitus; FFM: fat-free mass.

The association between HbA1c groups and anthropometric measurements and body composition parameters

Moderate positive correlations were found between HbA1c groups and anthropometric measurements (BMI: r=0.39; WC: r=0.42; WHR: r=0.37; p<0.001 for all). These findings indicate a association between increases in anthropometric measurements and higher glycemic levels. The strongest association among anthropometric parameters was observed with WC.

Weak-to-moderate positive associations were found between body composition parameters and HbA1c groups (body fat percentage r=0.22, fat mass r=0.31, and FFM r=0.20). This suggests that abdominal fat indicators may be more strongly associated with glycemic status compared to total body fat indicators.

After adjusting for antidiabetic medication use and regular physical activity (ANCOVA), differences between HbA1c groups remained significant for BMI, WC, WHR, body fat percentage, and fat mass (p<0.001 for all results), while no significant difference was found for FFM (p=0.202).

The results are presented in Table 4.

Association between HbA1c levels and anthropometric measurements and body composition parameters

In a general linear model (GLM) analysis adjusted for age and gender, it was found that WC and WHR were independently associated with HbA1c. WC showed a positive and independent association with HbA1c; each 1 cm increase in WC was associated with a 0.028-unit increase in HbA1c levels (β: 0.028; p=0.012). The strongest association was observed with WHR (β=4.301; p=0.006). While the association between BMI and HbA1c was borderline (p=0.065), no significant association was found with FFM (p=0.648). These findings suggest that measurements reflecting abdominal obesity may be more closely associated with glycemic status compared to general obesity and fat-free mass.

The results are presented in Table 5.

Table 4. Association between HbA1c groups and anthropometric measurements and body composition parameters

Variable	Spearman's r	p-value (Correlation)	p-value (ANCOVA)
BMI	0.39	<0.001	<0.001
WC	0.42	<0.001	<0.001
WHR	0.367	<0.001	<0.001
Body fat (%)	0.224	0.007	<0.001
Fat mass (kg)	0.306	<0.001	<0.001
FFM	0.201	0.015	0.202

Spearman's correlation analysis was used. Group comparisons were performed using ANCOVA adjusted for medication use and regular physical activity. p<0.05 was considered statistically significant.
BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio; FFM: fat-free mass.

Table 5. Association between HbA1c values and anthropometric measurements and body composition parameters

Variable	β (Estimate)	95% Confidence Interval	p-value
BMI	0.044	-0.094	0.065
WC	0.028	0.006-0.049	0.012
WHR	4.301	1.276-7.326	0.006
FFM	0.009	-0.079	0.648

Data are given as unstandardized β coefficients with 95% confidence intervals derived from age and gender- adjusted general linear models. p<0.05 was considered statistically significant.
BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio; FFM: fat-free mass.

Discussion

In this study, the relationships between HbA1c and anthropometric measurements and body composition parameters were evaluated in the control, preDM, and T2DM groups. The findings suggest that impaired glucose metabolism may be closely associated with abdominal adiposity, particularly from the early stages onward.

When anthropometric measurements were examined, BMI, WC, and WHR were lower in the control group, while similar values were observed in the preDM and T2DM groups. This pattern indicates that obesity—particularly abdominal adiposity—may be linked to glycemic impairment from early stages. Previous studies have also demonstrated that abdominal fat accumulation is strongly associated with insulin resistance and glucose metabolism.[14-16]

Although BMI is known to be associated with glycemic control,[17,18] the stronger associations observed for WC and WHR in this study are noteworthy. This finding supports the notion that fat distribution, rather than total body weight, may be a more important determinant of glycemic status. Consistent with our results, several studies have reported that WC and WHR are more strongly associated with HbA1c levels than BMI.[19,20] These findings are consistent with studies indicating that abdominal fat accumulation may be associated with an increased risk of diabetes even in individuals with normal BMI values.[3]

When body composition parameters were evaluated, it was observed that body fat percentage and mass were increased in the preDM and T2DM groups compared to the control group; however, no significant difference was found between these two groups. This suggests that an increase in body fat may occur in the early stages of dysglycemia. The literature also reports that increased body fat is associated with metabolic disorders and that higher fat levels have been observed in individuals with diabetes.[15,21,22]

The fact that no significant difference was observed between groups in terms of FFM suggests that body fat distribution may be a more decisive factor in the association with HbA1c compared to muscle mass. However, some studies have also reported that low muscle mass is associated with an increased risk of diabetes.[23,24] This highlights the complex and multifactorial nature of body composition in relation to glycemic regulation.

Correlation analyses revealed significant positive associations between HbA1c groups and anthropometric parameters as well as body composition parameters. The strongest correlations were observed with WC, BMI, and WHR, suggesting that measurements reflecting abdominal adiposity may be more strongly associated with glycemic status. Similar associations have previously been demonstrated for WC,[25] BMI,[17]and WHR.[26] In contrast, the associations with body fat percentage and body fat mass were weaker. One study reported that although fat mass is strongly associated with T2DM risk—particularly in women and younger individuals—it is not a better predictor than WC.[27]Additionally, another study found that short-term changes in fat mass do not significantly affect HbA1c levels in patients with diabetes.[28]

The fact that the results remained statistically significant even after adjusting for regular physical activity and the use of antidiabetic medications indicates that the observed associations are relatively independent of these factors. However, variables such as duration of medication use and treatment adherence, along with the cross-sectional study design, represent key limitations of this study. Furthermore, although age and gender were included as adjustment variables in the generalized linear models, residual confounding related to age differences between the study groups cannot be completely excluded.

One of the key contributions of this study is the combined evaluation of anthropometric and body composition parameters across different glycemic states. In multivariate analyses, WC and, particularly, WHR were found to be more strongly associated with HbA1c compared to BMI and FFM. Because WHR is expressed on a narrower numerical scale than BMI and WC, the magnitude of the β coefficient should be interpreted cautiously and not considered a direct measure of effect size. The observed relationship between increases in WC and HbA1c levels supports the potential importance of abdominal obesity indicators. The fact that BMI was only marginally associated may be explained by its limitations in reflecting fat distribution. In addition, no evidence of substantial multicollinearity was observed in the regression analyses, supporting the stability of the reported associations.

Overall, the findings indicate that parameters reflecting abdominal fat distribution are more closely associated with glycemic status. However, due to the cross-sectional design of the study, these associations should

not be interpreted causally. From a clinical perspective, incorporating WC and, in particular, WHR measurements into routine evaluations may contribute to a more accurate assessment of metabolic risk.

Conclusion

In this study, the relationships between HbA1c levels and anthropometric as well as body composition parameters were evaluated, and indicators reflecting abdominal obesity (WC and WHR) were found to have stronger associations with HbA1c compared to BMI. These findings suggest that considering abdominal obesity indicators may be beneficial in the assessment of glycemic status. However, due to the cross-sectional design, causal inferences cannot be made. Further large-scale and prospective studies are needed to better elucidate these relationships.

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Author contributions

Conception and design: G.Ç.A., A.D.; Data acquisition: G.Ç.A., B.E., E.S.Ş.; Data analysis: G.Ç.A.; Data interpretation: G.Ç.A., A.D., E.F.O.; Drafting of the manuscript: G.Ç.A., A.D., B.E., E.F.O., E.S.Ş.; Critical revision of the manuscript: G.Ç.A., A.D. All authors reviewed the results, approved the final version of the manuscript, and agreed to be accountable for all aspects of this study.

Ethical approval

This study was approved by the Ankara Bilkent City Hospital Scientific and Ethical Review Board for Medical Research (TABED) (Date: 2 October, 2024, Decision/Protocol No: TABED 2 – 24 – 553). Informed consent was obtained from all participants involved in this study.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that this study was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Generative AI statement

The authors declare that no generative AI or AI-assisted technologies were used in the writing or preparation of this study.

References

1. International Diabetes Federation. IDF diabetes atlas. 10th ed. Brussels, Belgium: International Diabetes Federation; 2021.
2. Turkish Society of Endocrinology and Metabolism. Obesity diagnosis and treatment guidelines. Available at: https://file.temd.org.tr/Uploads/publications/guides/documents/obezitetanitedavikilavizu-2024.pdf (Accessed on April 1, 2026).
3. Jin X, Liu J, Cao Q, et al. Normal-weight central obesity: implications for diabetes mellitus. Front Nutr. 2023;10:1239493. [Crossref]
4. Chung TL, Liu YH, Wu PY, Huang JC, Chen SC. Sex difference in the associations among obesity-related indices with incidence of diabetes mellitus in a large Taiwanese population follow-up study. Front Public Health. 2023;11:1094471. [Crossref]
5. Hou X, Chen S, Hu G, et al. Stronger associations of waist circumference and waist-to-height ratio with diabetes than BMI in Chinese adults. Diabetes Res Clin Pract. 2019;147:9-18. [Crossref]
6. Sbrignadello S, Göbl C, Tura A. Bioelectrical impedance analysis for the assessment of body composition in sarcopenia and type 2 diabetes. Nutrients. 2022;14(9):1864. [Crossref]

7. Haines MS, Leong A, Porneala BC, Meigs JB, Miller KK. Association between muscle mass and diabetes prevalence independent of body fat distribution in adults under 50 years old. Nutr Diabetes. 2022;12(1):29. [Crossref]
8. Liu ZJ, Zhu CF. Causal relationship between insulin resistance and sarcopenia. Diabetol Metab Syndr. 2023;15(1):46. [Crossref]
9. Majety P, Lozada Orquera FA, Edem D, Hamdy O. Pharmacological approaches to the prevention of type 2 diabetes mellitus. Front Endocrinol. 2023;14:1118848. [Crossref]
10. Aghaei M, Joukar F, Hasanipour S, Ranjbar ZA, Naghipour M, Mansour-Ghanaei F. The association between waist-to-hip ratio (WHR) with diabetes in the PERSIAN Guilan cohort study population. BMC Endocr Disord. 2024;24(1):113. [Crossref]
11. Ministry of Health of the Republic of Türkiye, General Directorate of Public Health. Turkish dietary guidelines (TÜBER) 2022. Ankara, Türkiye: Ministry of Health of the Republic of Türkiye; 2022. Available at: https://hsgm.saglik.gov.tr/depo/birimler/saglikli-beslenme-ve-hareketli-hayat-db/Dokumanlar/Rehberler/Turkiye_Beslenme_Rehber_TUBER_2022_min.pdf (Accessed on April 1, 2026).
12. ElSayed NA, Aleppo G, Aroda VR, et al. 2. classification and diagnosis of diabetes: standards of care in diabetes-2023. Diabetes Care. 2023;46(Suppl 1):S19-S40. [Crossref]
13. Lorcu F. Data analysis with examples: SPSS application. Ankara, Türkiye: Detay Yayıncılık; 2015.
14. Ross R, Neeland IJ, Yamashita S, et al. Waist circumference as a vital sign in clinical practice: a consensus statement from the IAS and ICCR working group on visceral obesity. Nat Rev Endocrinol. 2020;16(3):177-189. [Crossref]
15. Ye M, Robson PJ, Eurich DT, Vena JE, Xu JY, Johnson JA. Anthropometric changes and risk of diabetes: are there sex differences? A longitudinal study of Alberta's Tomorrow Project. BMJ Open. 2019;9(7):e023829. [Crossref]
16. Mohammad A, Ziyab AH, Mohammad T. Anthropometric and DXA-derived measures of body composition in relation to pre-diabetes among adults. BMJ Open Diabetes Res Care. 2023;11(5):e003412. [Crossref]
17. Deng L, Jia L, Wu XL, Cheng M. Association between body mass index and glycemic control in type 2 diabetes mellitus: a cross-sectional study. Diabetes Metab Syndr Obes. 2025;18:555-563. [Crossref]
18. Ge Q, Li M, Xu Z, et al. Comparison of different obesity indices associated with type 2 diabetes mellitus among different sex and age groups in Nantong, China: a cross-section study. BMC Geriatr. 2022;22(1):20. [Crossref]
19. Oumer A, Ale A, Tariku Z, Hamza A, Abera L, Seifu A. Waist-to-hip circumference and waist-to-height ratio could strongly predict glycemic control than body mass index among adult patients with diabetes in Ethiopia: ROC analysis. PLoS One. 2022;17(11):e0273786. [Crossref]
20. Chowdhary A, Thirunavukarasu S, Jex N, et al. Coronary microvascular function and visceral adiposity in patients with normal body weight and type 2 diabetes. Obesity (Silver Spring). 2022;30(5):1079-1090. [Crossref]
21. Gomez-Peralta F, Abreu C, Cruz-Bravo M, et al. Relationship between "a body shape index (ABSI)" and body composition in obese patients with type 2 diabetes. Diabetol Metab Syndr. 2018;10:21. [Crossref]
22. Wondmkun YT. Obesity, insulin resistance, and type 2 diabetes: associations and therapeutic implications. Diabetes Metab Syndr Obes. 2020;13:3611-3616. [Crossref]
23. Suárez R, Andrade C, Bautista-Valarezo E, et al. Low muscle mass index is associated with type 2 diabetes risk in a Latin-American population: a cross-sectional study. Front Nutr. 2024;11:1448834. [Crossref]
24. Kim K, Park SM. Association of muscle mass and fat mass with insulin resistance and the prevalence of metabolic syndrome in Korean adults: a cross-sectional study. Sci Rep. 2018;8(1):2703. [Crossref]
25. Zhen J, Liu S, Zhao G, et al. Association of waist circumference with haemoglobin A1c and its optimal cutoff for identifying prediabetes and diabetes risk in the Chinese population. Intern Emerg Med. 2022;17(7):2039-2044. [Crossref]
26. Bala M, Meenaskshi, Aggarwal S. Correlation of body mass index and waist/hip ratio with glycated hemoglobin in prediabetes. EJIFCC. 2019;30(3):317-324.
27. Masrouri S, Ebrahimi N, Soraneh S, Azizi F, Hadaegh F. Association of relative fat mass with the incidence of type 2 diabetes: over a decade follow-up from the TLGS. Int J Obes (Lond). 2025;49(11):2229-2240. [Crossref]
28. Nomura K, Inagaki S, Muramae N, et al. Association of short-term changes in HbA1c with body composition and the importance of muscle maintenance in patients with type 2 diabetes. J Diabetes Complications. 2024;38(6):108746. [Crossref]