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Waist/neck and TG/HDL-C ratios as predictors of insulin resistance in overweight and obese non-diabetic adults: A cross-sectional study

Diyabetik olmayan aşırı kilolu/obez yetişkinlerde insülin direncinin belirleyicileri olarak bel-boyun oranı ve TG/HDL-C oranı: Kesitsel bir çalışma

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WNR and TG/HDL-C in Insulin Resistance
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Developments and Experiments in Health and Medicine
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RESEARCH ARTICLE
Pages:379-388

ABSTRACT

BACKGROUND

Simple anthropometric ratios and lipid-based indices may help identify insulin resistance (IR) in routine practice, especially where clamp techniques are not feasible. We evaluated anthropometric ratios, including the waist/neck ratio (WNR) and the waist/height ratio (WHtR), and the triglyceride/high-density lipoprotein cholesterol (TG/HDL-C) ratio as potential predictors of IR in overweight and obese non-diabetic adults.

METHODS

This cross-sectional study included 49 non-diabetic adults aged 18–75 years with body mass index (BMI) values of ≥ 25 kg/m². Anthropometric measurements (waist, neck, hips, height, and weight) and fasting biochemical parameters were obtained. IR was defined as a homeostasis model assessment of insulin resistance (HOMA-IR) value of ≥ 2.5. Pearson correlations were used to assess relationships between HOMA-IR and the analyzed ratios. Variables associated with IR were evaluated using multivariate logistic regression.

RESULTS

The mean age of the study's participants was 43.24 ± 11.20 years, 77.6% were female, and the mean BMI was 33.80 ± 5.15 kg/m². IR was present in 25 of 49 participants (51.0%). WNR (r = 0.293, p = 0.041) and WHtR (r = 0.341, p = 0.016) correlated positively with HOMA-IR values, whereas the neck/weight ratio correlated negatively (r = –0.358, p = 0.012). The TG/HDL-C ratio correlated positively with HOMA-IR (r = 0.344, p = 0.015). In multivariate logistic regression, the TG/HDL-C (odds ratio [OR]: 1.432; 95% confidence interval [CI]: 1.050–1.953; p = 0.023) and WNR (OR: 15.469; 95% CI: 1.446–165.541; p = 0.024) remained independently associated with IR.

CONCLUSION

In overweight and obese non-diabetic adults, the TG/HDL-C ratio and WNR were independently associated with IR, supporting their use as accessible screening tools. The WHtR and additional exploratory ratios such as neck/weight also showed significant correlations with HOMA-IR and may merit further validation in larger cohorts.

KEYWORDS

Anthropometry, cholesterol ratio, HOMA-IR, insulin resistance, obesity, triglyceride/HDL waist/height ratio, waist/neck ratio

ÖZ

AMAÇ

Basit antropometrik oranlar ve lipid bazlı indeksler, özellikle kelepçe tekniklerinin mümkün olmadığı durumlarda, rutin uygulamada insülin direncini (İR) belirlemeye yardımcı olabilir. Bu çalışmada, aşırı kilolu/obez diyabetik olmayan yetişkinlerde İR'nin potansiyel belirleyicileri olarak bel-boy oranı (WNR) ve bel-boy oranı (WHtR) dahil olmak üzere antropometrik oranları ve trigliserit/yüksek yoğunluklu lipoprotein kolesterol (TG/HDL-C) oranını değerlendirdik.

GEREÇ YÖNTEM

Bu kesitsel çalışmada, vücut kitle indeksi (VKİ) ≥ 25 kg/m² olan 49 diyabetik olmayan yetişkin (18-75 yaş arası) dahil edildi. Antropometrik ölçümler (bel, boyun, kalça, boy ve ağırlık) ve açlık biyokimyasal parametreleri elde edildi. İR, HOMA-IR ≥ 2,5 olarak tanımlandı. HOMA-IR ile aday oranlar/indeksler arasındaki ilişkiler Pearson korelasyonları ile değerlendirildi. İnsülin direnci (IR) ile ilişkili değişkenler, çok değişkenli lojistik regresyon kullanılarak değerlendirildi.

BULGULAR

Ortalama yaş 43,24 ± 11,20 yıl; %77,6'sı kadın; ortalama BMI 33,80 ± 5,15 kg/m² idi. 49 katılımcının 25'inde (%51,0) IR mevcuttu. WNR (r = 0,293, p = 0,041) ve WHtR (r = 0,341, p = 0,016) HOMA-IR ile pozitif korelasyon gösterirken, boyun-ağırlık oranı negatif korelasyon gösterdi (r = –0,358, p = 0,012). TG/HDL-C oranı HOMA-IR ile pozitif korelasyon gösterdi (r = 0,344, p = 0,015). Çok değişkenli lojistik regresyonda, TG/HDL-C (olasılık oranı (OR) 1,432; %95 CI 1,050–1,953; p = 0,023) ve WNR (OR 15,469; %95 CI 1,446–165,541; p = 0,024) IR ile bağımsız olarak ilişkili kalmıştır.

SONUÇ

Diyabetik olmayan, aşırı kilolu/obez yetişkinlerde, TG/HDL-C oranı ve WNR, IR ile bağımsız olarak ilişkili olup, erişilebilir tarama araçları olarak kullanımlarını desteklemektedir. WHtR ve ek keşifsel oranlar (örneğin, boyun-kilo oranı), HOMA-IR ile anlamlı korelasyonlar göstermiş olup, daha büyük kohortlarda daha fazla doğrulamayı hak etmektedir.

ANAHTAR KELİMELER

Antropometri, bel-boy oranı, HOMA-IR, insülin direnci, kolesterol oranı, obezite, trigliserit-HDL

Developments and Experiments in Health and Medicine
Year: 2026
Volume: 40
Issue:3
RESEARCH ARTICLE
Pages:379-388

Insulin resistance (IR) is a central pathophysiological mechanism linking excess adiposity to type 2 diabetes and cardiometabolic disease (1–4). While the hyperinsulinemic-euglycemic clamp technique is the reference method for quantifying insulin sensitivity, it is impractical for routine care and most clinical studies (5). Fasting surrogate indices such as the homeostasis model assessment of insulin resistance (HOMA-IR) are therefore widely used, but their clinical utility depends on pragmatic, low-cost predictors that can identify individuals at higher risk (6,7).

Anthropometric measures reflecting body fat distribution, particularly central and upper-body adiposity, have been associated with IR and adverse cardiometabolic profiles (8–12). Waist circumference and the waist/height ratio (WHtR) capture central adiposity and may outperform body mass index (BMI) for cardiometabolic risk stratification across populations (13–15). Neck circumference has emerged as a proxy for upper-body subcutaneous fat and has been linked to visceral adiposity and IR independently of BMI and waist circumference in some cohorts (16–19). However, single measures can be influenced by body size and measurement variability. Therefore, ratios such as the waist/neck ratio (WNR) may better integrate central and upper-body adiposity.

Biochemical markers may further improve such screening. The triglyceride/high-density lipoprotein cholesterol (TG/HDL-C) ratio is a simple lipid-based marker associated with IR and metabolic risk and has shown utility in identifying insulin-resistant phenotypes (7,20). Additionally, indices such as the triglyceride-glucose (TyG) index and the Metabolic Score for Insulin Resistance (METS-IR) have been proposed as accessible surrogate measures of insulin sensitivity (21–23).

In this cross-sectional study, we assessed associations between the WNR and WHtR as anthropometric ratios, the TG/HDL-C ratio, and IR (defined as HOMA-IR of ≥ 2.5) in overweight and obese non-diabetic adults.

Materials and Methods

Study design and participants

This cross-sectional study was conducted in the Endocrinology Outpatient Clinic of İstanbul Sultan Abdulhamid Han Training and Research Hospital (İstanbul, Türkiye) between January 2022 and December 2022. Adults aged 18–75 years with BMI of ≥25 kg/m2 and without known diabetes were eligible for inclusion. Exclusion criteria were diagnosed diabetes mellitus, use of medications affecting glucose metabolism (including antidiabetic agents, systemic glucocorticoids, or antipsychotics), pregnancy, chronic kidney or liver disease, active infection or inflammatory disease, malignancy, and known thyroid dysfunction. All participants provided written informed consent prior to inclusion.

This study was approved by the Haseki Training and Research Hospital Ethics Committee (approval number: 36-2023; date: 19.04.2023) and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants involved in the study.

Anthropometric measurements

Anthropometric measurements were performed by a single trained endocrinologist using a standardized protocol. Body weight was measured to the nearest 0.1 kg using a calibrated digital scale and height to the nearest 0.1 cm using a stadiometer; BMI was calculated as weight/height2 (kg/m^2). Waist circumference was measured at the narrowest point between the lower costal margin and the iliac crest at the end of normal expiration. Neck circumference was measured at the level of the thyroid cartilage with the head in the Frankfort horizontal plane. Hip circumference was measured at the level of maximum extension of the hips. The derived anthropometric ratios included the WNR, WHtR, waist/weight ratio, and neck/weight ratio.

Laboratory measurements and indices

Fasting blood samples were obtained after an overnight fast of ≥8 h. Plasma glucose, total cholesterol, triglycerides, HDL-C, and low-density lipoprotein cholesterol were measured using standard automated assays. Fasting insulin was measured using the institutional immunoassay. HOMA-IR values were calculated as follows (6):

HOMA-IR = [Fasting glucose (mmol/L) × Fasting insulin (μIU/mL)] / 22.5. IR was defined a priori as HOMA-IR of ≥ 2.5; population-based data from Türkiye report HOMA1-IR threshold values of approximately 2.46 (24). The TG/HDL-C ratio was calculated as fasting triglycerides divided by HDL-C.

Developments and Experiments in Health and Medicine
Year: 2026
Volume: 40
Issue:3
RESEARCH ARTICLE
Pages:379-388

For descriptive correlation plots, the TyG index was computed as ln[TG (mg/dL) × FG (mg/dL)/2] (21,22).

Statistical analysis

Continuous variables were presented as mean ± standard deviation and categorical variables as counts and percentages. Between-group comparisons (IR+ vs. IR–) were performed with independent-samples t-tests for continuous variables and chi-square tests for categorical variables as appropriate. Pearson correlation coefficients (r) were calculated to assess associations between HOMA-IR values and anthropometric ratios and lipid parameters. Multivariate logistic regression analyses were performed using the enter method. The primary model included age and sex as covariates. Given the potential collinearity between BMI and anthropometric ratios, BMI was not included in the primary model. A secondary sensitivity analysis was conducted including BMI to assess the robustness of the findings. Results of the regression models were presented as odds ratios (ORs) with 95% confidence intervals (CIs). Receiver operating characteristic (ROC) curve analysis was performed to evaluate the discriminative ability of the WNR and TG/HDL-C ratio. Optimal cut-off values were determined using the Youden index. Two-sided values of $p < 0.05$ were considered statistically significant.

Results

Participant characteristics

Forty-nine non-diabetic adults with BMI of ≥25 kg/m² (77.6% female) were included in this study. Based on HOMA-IR values of ≥ 2.5, 25 participants (51.0%) were classified as insulin-resistant (IR+) and 24 as non-insulin-resistant (IR–). Baseline characteristics by IR status are summarized in Table 1.

Table 1. Characteristics of participants stratified by insulin resistance status (HOMA-IR ≥ 2.5).

Variable	IR– (n=24) Mean ± SD	IR+ (n=25) Mean ± SD	p-value
Age (years)	42.88 ± 11.26	43.60 ± 11.36	0.823
Sex (F/M)	19/5	19/6	0.791
Height (cm)	161.58 ± 6.96	163.72 ± 8.64	0.346
BMI (kg/m²)	31.71 ± 4.78	35.81 ± 4.75	0.004
Waist circumference (cm)	96.58 ± 11.86	108.00 ± 14.29	0.004
Neck circumference (cm)	35.06 ± 2.64	36.12 ± 2.89	0.188
LDL cholesterol (mg/dL)	110.13 ± 31.19	101.36 ± 26.87	0.297
HDL cholesterol (mg/dL)	59.13 ± 14.94	48.16 ± 12.50	0.008
Triglycerides (mg/dL)	103.74 ± 65.09	165.16 ± 85.93	0.007
Albumin (g/L)	44.75 ± 2.61	44.70 ± 2.20	0.947
Hemoglobin (g/dL)	13.06 ± 1.42	13.43 ± 1.48	0.383
TG/HDL ratio	2.06 ± 2.15	4.09 ± 3.24	0.013
Waist/neck ratio	2.76 ± 0.29	2.99 ± 0.35	0.014
Waist/height ratio	0.60 ± 0.08	0.66 ± 0.07	0.006

IR, insulin resistance; SD, standard deviation; F, female; M, male; BMI, body mass index; LDL, low-density lipoprotein; HDL, high-density lipoprotein; TG, triglycerides.

Developments and Experiments in Health and Medicine
Year: 2026
Volume: 40
Issue:3
RESEARCH ARTICLE
Pages:379-388

Pearson correlations between HOMA-IR values and selected anthropometric and lipid variables are shown in Table 2. HOMA-IR values correlated positively with body weight (r = 0.397, p = 0.005), BMI (r = 0.324, p = 0.023), and waist circumference (r = 0.409, p = 0.004). Among lipid parameters, triglycerides (r = 0.346, p = 0.015) and the TG/HDL-C ratio (r = 0.344, p = 0.015) were positively correlated with HOMA-IR, whereas HDL-C was inversely correlated (r = –0.411, p = 0.003). Of the anthropometric ratios, WNR correlated with HOMA-IR (r = 0.293, p = 0.041), and WHtR also correlated with HOMA-IR (r = 0.341, p = 0.016). In a multivariate logistic regression model adjusted for age and sex (Table 3), both the TG/HDL-C ratio (OR: 1.535; 95% CI: 1.090–2.161; p = 0.014) and WNR (OR: 15.493; 95% CI: 1.623–147.892; p = 0.017) were independently associated with IR. In sensitivity analysis additionally adjusted for BMI (Table 4), the association of the WNR was attenuated and did not remain statistically significant, whereas the TG/HDL-C ratio retained borderline significance.

ROC analysis demonstrated that the TG/HDL-C ratio had good discriminative ability for IR, with an area under the curve (AUC) of 0.749 (95% CI: 0.611–0.887; p < 0.001). The WNR showed moderate discriminative ability, with an AUC of 0.692 (95% CI: 0.542–0.841; p = 0.012), as seen in Figure 2 and Table 5. The optimal cut-off value for the TG/HDL-C ratio was approximately 1.44, yielding sensitivity of 84% and specificity of 54%. For the WNR, a cut-off value of approximately 2.80 provided sensitivity of 80% and specificity of 54%.

Table 2. Pearson correlations between HOMA-IR and selected variables.

Variable	r	p-value
Weight	0.397	0.005
BMI	0.324	0.023
Waist circumference	0.409	0.004
Neck circumference	0.280	0.051
LDL cholesterol	–0.295	0.039
Triglycerides	0.346	0.015
HDL cholesterol	–0.411	0.003
TG/HDL ratio	0.344	0.015
Waist/neck ratio	0.293	0.041
Waist/height ratio	0.341	0.016

HOMA-IR; homeostasis model assessment of insulin resistance, BMI; body mass index, LDL; low-density lipoprotein, HDL; high-density lipoprotein, TG; triglycerides.

Developments and Experiments in Health and Medicine
Year: 2026
Volume: 40
Issue:3
RESEARCH ARTICLE
Pages:379-388

Table 3. Multivariate logistic regression analysis adjusted for age and sex.

Variable	OR	95% CI	p-value
Age	1.012	0.954–1.074	0.689
Male sex	2.870	0.398–20.698	0.296
TG/HDL-C ratio	1.535	1.090–2.161	**0.014**
Waist/neck ratio	15.493	1.623–147.892	**0.017**

Model fit; Hosmer–Lemeshow p = 0.785, Nagelkerke R2 = 0.355, OR; odds ratio, CI; confidence interval, TG; triglyceride, HDL-C; high-density lipoprotein cholesterol.

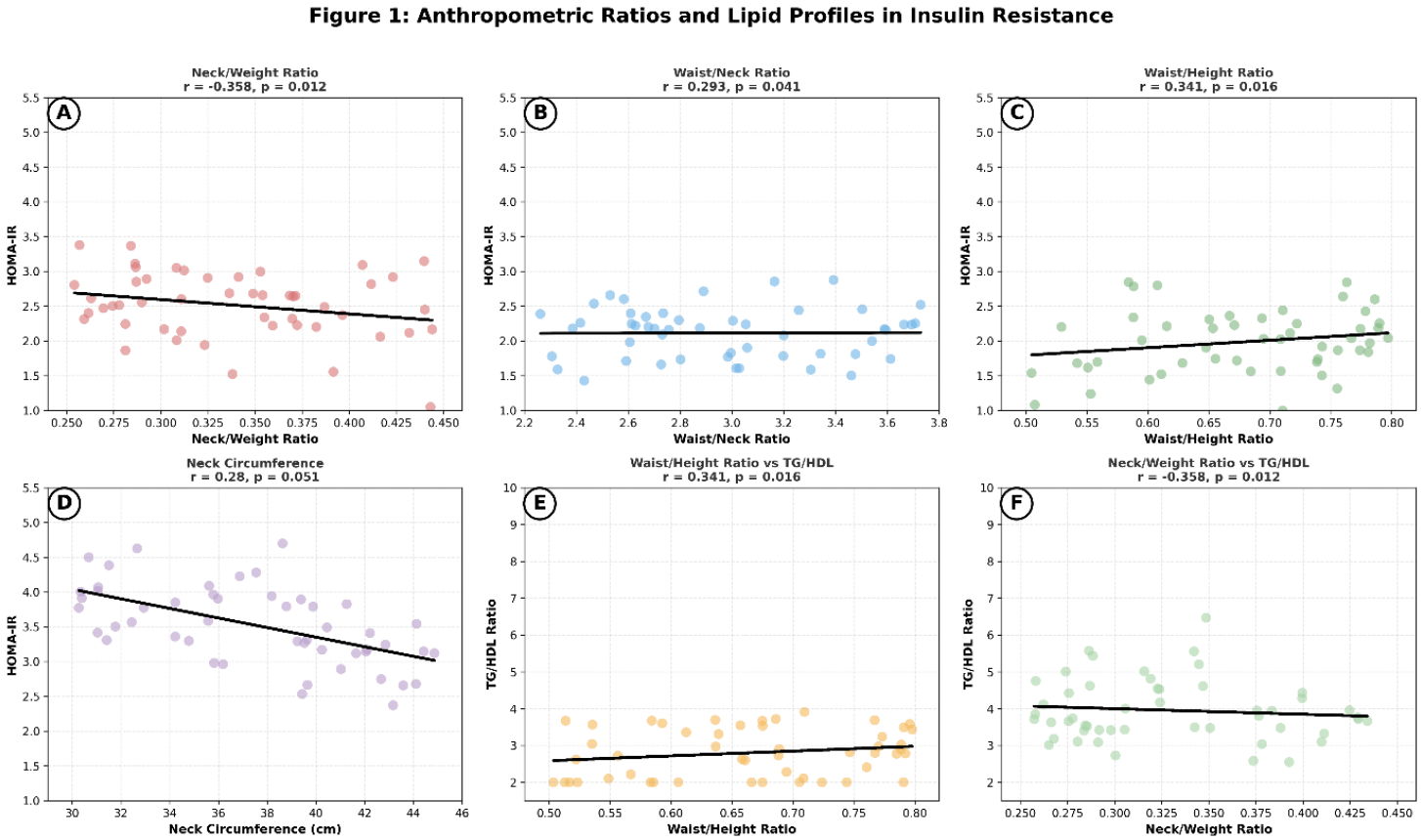


Figure 1. Anthropometric ratios and lipid profiles in insulin resistance. Six scatter plots demonstrate individual and combined associations with metabolic markers. A) Neck/weight ratio versus HOMA-IR scatter plot demonstrates a significant negative correlation (r = –0.358, p = 0.012) between these variables. B) Waist/neck ratio versus HOMA-IR scatter plot shows a positive but modest association (r = 0.293, p = 0.041). C) Waist/height ratio versus HOMA-IR scatter plot exhibits a moderate positive correlation (r = 0.341, p = 0.016). D) Neck circumference versus HOMA-IR scatter plot presents a borderline significant negative trend (r = 0.28, p = 0.051). E) Waist/height ratio versus triglyceride/high-density lipoprotein cholesterol (TG/HDL) ratio scatter plot demonstrates a positive correlation (r = 0.341, p = 0.016) similar to that observed for HOMA-IR. F) Neck/weight ratio versus TG/HDL ratio scatter plot has an inverse relationship similar to that seen for HOMA-IR.

Developments and Experiments in Health and Medicine
Year: 2026
Volume: 40
Issue:3
RESEARCH ARTICLE
Pages:379-388

Table 4. Multivariate logistic regression analysis additionally adjusted for BMI (sensitivity analysis).

Variable	OR	95% CI	p-value
Age	1.013	0.955–1.075	0.663
BMI	1.064	0.875–1.294	0.535
TG/HDL-C ratio	1.377	1.000–1.897	**0.050**
Waist/neck ratio	8.114	0.331–199.021	0.200

Model fit; Hosmer–Lemeshow p = 0.750, Nagelkerke R2 = 0.340. OR; Odds ratio, CI; confidence interval, BMI; body mass index, TG; triglyceride, HDL-C; high-density lipoprotein cholesterol.

Table 5. ROC curve analysis of variables for predicting insulin resistance.

Variable	AUC	95% CI	p-value
TG/HDL-C ratio	0.749	0.611–0.887	**< 0.001**
Waist/neck ratio	0.692	0.542–0.841	**0.012**

ROC; receiver operating characteristic; AUC; area under the curve, CI; confidence interval, TG; triglyceride, HDL-C;high-density lipoprotein cholesterol.

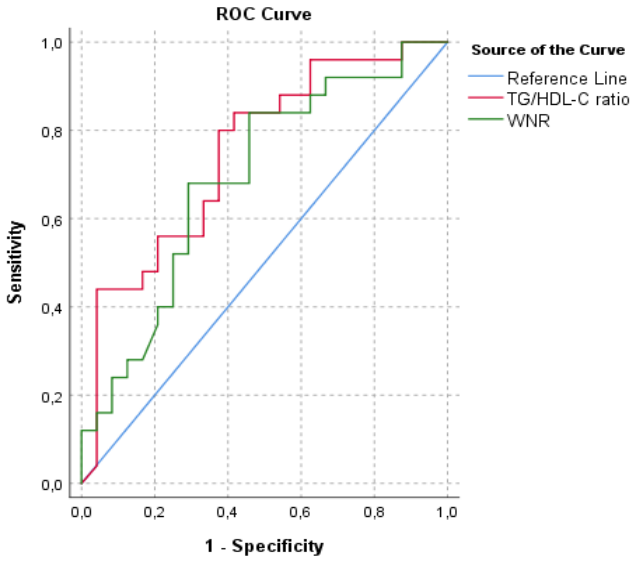


Figure 2. ROC curves of waist/neck ratio (WNR) and triglyceride/high-density lipoprotein cholesterol (TG/HDL-C) ratio for predicting insulin resistance.

Developments and Experiments in Health and Medicine
Year: 2026
Volume: 40
Issue:3
RESEARCH ARTICLE
Pages:379-388

Discussion

In this cross-sectional study of overweight and obese non-diabetic adults, we found that both the TG/HDL-C ratio as an easily calculated lipid marker and the WNR as an anthropometric ratio integrating central and upper-body dimensions were independently associated with IR, defined by HOMA-IR of ≥2.5. The WHtR also correlated with HOMA-IR scores, and multi-panel visualization of the results (Figure 1) contextualized these associations within the broader distribution of HOMA-IR values and related indices.

Central adiposity is a key determinant of IR and cardiometabolic risk. Waist circumference and WHtR correlated with HOMA-IR in our cohort, consistent with prior evidence that the WHtR can provide strong discrimination of cardiometabolic risk across populations (13–15). Another notable observation was the independent association between the WNR and IR. Neck circumference is a proxy for upper-body subcutaneous fat and has been associated with visceral adiposity and IR (16–19). By relating waist circumference to neck size, the WNR may capture a pattern of fat partitioning linked to IR. In the present study, WNR values correlated with HOMA-IR values and remained independently predictive of IR status.

The TG/HDL-C ratio emerged as an independent predictor of IR in this study, consistent with previous work showing that this simple lipid ratio can help in identifying insulin-resistant individuals (7,20). The attenuation of the WNR after adjustment for BMI likely reflects shared variance between general and regional adiposity measures rather than absence of a true association. Importantly, the WNR remained independently associated with insulin resistance in the model adjusted for age and sex, supporting its potential role as a practical anthropometric marker.

These findings should be interpreted in the context of the study's small sample size and require validation in larger cohorts. Because TG and HDL-C values are routinely measured, the TG/HDL-C ratio may complement anthropometric screening in outpatient practice.

ROC analysis further supported the clinical utility of the TG/HDL-C ratio and WNR. The TG/HDL-C ratio demonstrated better discriminative performance compared to the WNR, suggesting that metabolic markers may have stronger predictive value than anthropometric indices alone. However, the WNR still showed moderate accuracy and may offer additional practical value due to its simplicity and ease of measurement.

The exploratory inverse correlation between the neck/weight ratio and HOMA-IR may reflect body-size scaling effects; this observation should be interpreted cautiously and validated externally.

Limitations of the study include the small sample size, female predominance, and cross-sectional design. IR was assessed using HOMA-IR values rather than clamp-derived measures, and these values may be influenced by assay variability (6). Nevertheless, the findings support the potential clinical utility of the WNR and TG/HDL-C as accessible markers of IR in overweight and obese non-diabetic adults.

Conclusion

In overweight and obese non-diabetic adults, the TG/HDL-C ratio and WNR were independently associated with IR as defined by HOMA-IR values. These simple, low-cost measures may support risk stratification in outpatient settings and warrant validation in larger prospective cohorts.

Developments and Experiments in Health and Medicine
Year: 2026
Volume: 40
Issue:3
RESEARCH ARTICLE
Pages:379-388

Conflicts of Interest
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Conceptualization: İ.E.; methodology: İ.E.; investigation: İ.E. and E.H.; data curation: İ.E.; formal analysis: İ.E.; writing—original draft preparation: İ.E.; writing—review and editing: İ.E. and E.H.; supervision: İ.E. All authors have read and agreed to the published version of the manuscript.
Institutional Review Board Statement
This study was approved by the Haseki Training and Research Hospital Ethics Committee (approval number: 36-2023; date: 19.04.2023) and conducted in accordance with the Declaration of Helsinki.Source of funding
Informed Consent Statement
Written informed consent was obtained from all participants involved in the study.
Data Availability Statement
De-identified data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to institutional and ethical approvals.

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Developments and Experiments in Health and Medicine
Year: 2026
Volume: 40
Issue:3
RESEARCH ARTICLE
Pages:379-388

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