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Original Article

Assessing the Impact of Anthropometric Measurements on Osteoporosis Risk in Postmenopausal Women

Menopoz Sonrası Kadınlarda Osteoporoz Riskini Değerlendirmede Antropometrik Ölçümlerin Etkisi

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Abstract

Aim: This study evaluates various anthropometric measurements, including BMI, Waist-to-Hip Ratio (WHR), Waist-to-Height Ratio (WHtR), Conicity Index (C-index), and Visceral Adiposity Index (VAI), to determine their association with osteoporosis in postmenopausal women.

Material and Method: In this cross-sectional study, 304 postmenopausal women aged 45-75 years from a gynecology and menopause clinic participated. Dual-Energy X-ray Absorptiometry (DEXA) was used to assess Bone Mineral Density (BMD). Anthropometric measurements (waist circumference, hip circumference) were recorded, and indices (BMI, WHR, WHtR, C-index, VAI) were calculated. Demographic and medical histories were collected through questionnaires.

Results: BMI showed a positive association with lumbar spine ($\beta = 0.503$, $p = 0.001$) and femoral neck T-scores ($\beta = 0.413$, $p = 0.004$). WHR ($\beta = 0.256$, $p = 0.002$) was positively associated with BMD, while C-index ($\beta = -0.455$, $p = 0.001$) was negatively correlated with femoral neck T-scores. Lower BMI and WHtR values were found predictive for osteoporosis according to the ROC curve analysis. While BMI was found as the strongest predictor, VAI did not significantly differentiate between groups ($p > 0.05$).

Conclusion: For assessment of osteoporosis risk in postmenopausal women; anthropometric indices like CI, WHR, and WHtR may be combined with BMI. In populations with different body compositions, these measures in clinical practice can improve osteoporosis screening and management.

Keywords: Anthropometric Indices; Body Fat Distribution; Body Mass Index (BMI); Osteoporosis; Postmenopausal Women

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Öz

Amaç: Bu çalışma, Vücut Kitle İndeksi (VKİ), Bel-Kalça Oranı (WHR), Bel-Yükseklik Oranı (WHtR), Konisite İndeksi (CI) ve Visceral Adipozite İndeksi (VAI) gibi çeşitli antropometrik ölçümlerin postmenopozal kadınlarda osteoporoz ile ilişkisini değerlendirmektedir.

Gereç ve Yöntem: Bu kesitsel çalışmaya, 45-75 yaş arası 304 postmenopozal kadın katılmıştır. Kemik Mineral Yoğunluğu (KMD), İkili Enerji X-Işını Absorpsiyometrisi (DEXA) kullanılarak değerlendirilmiştir. Antropometrik ölçümler (ağırlık, boy, bel çevresi, kalça çevresi) kaydedilmiş ve indeksler (VKI, WHR, WHtR, CI, VAI) hesaplanmıştır. Demografik ve tıbbi veriler toplanmıştır.

Bulgular: VKİ, lomber omurga (β = 0.503, p = 0.001) ve femoral boyun T-skorları (β = 0.413, p = 0.004) ile pozitif ilişki göstermiştir. WHR (β = 0.256, p = 0.002) KMD ile pozitif ilişkilidir, CI (β = -0.455, p = 0.001) ise femoral boyun T-skorları ile negatif korelasyona sahiptir. ROC eğrisi analizleri, düşük VKİ ve WHtR değerlerinin osteoporozu öngördüğünü, VKİ'nin en güçlü öngörücü olduğunu göstermiştir. VAI, osteoporoz risk kategorilerini anlamlı şekilde ayırt edememiştir (p > 0.05).

Sonuç: CI, WHR ve WHtR gibi antropometrik indeksler, VKİ ile birlikte kullanıldığında postmenopozal kadınlarda osteoporoz riskinin değerlendirilmesini artırmaktadır. Bu ölçümlerin klinik pratiğe entegrasyonu, osteoporoz tarama ve yönetimini özellikle çeşitli vücut kompozisyonlarına sahip popülasyonlarda iyileştirebilir.

Anahtar Kelimeler: Antropometrik ölçümler; Osteoporoz; Postmenopozal; Vücut kitle indeksi; Vücut yağ dağılımı

1. Introduction

Osteoporosis is an important health issue has a significant impact on morbidity and mortality worldwide (1). The osteoporosis is defined as a " progressive systemic skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fracture" by World Health Organization. Dual-energy X-ray absorptiometry (DEXA) which assesses bone mineral density (BMD) is the most common diagnostic tool for osteoporosis (2).

Positive correlation between Body Mass Index (BMI) and BMD has been studied. Mechanical loading in obese people potentially explains higher BMD in this population. However, BMD alone may not fully reflect bone health, particularly in obese or diabetic patients (3-5).

BMI is the simple and easy calculation formula for assessing obesity and related health risks in people. However, it has significant limitations which leads to potential misclassifications like; it does not differentiate between fat and muscle mass nor does it provide information on fat distribution (6). For instance, individuals with high muscle mass might be categorized as overweight or obese even if they have low body fat, while those with a normal BMI may still have significant visceral fat, which poses hidden health risks (7). Visceral fat plays an important role for human health. Specific hormones and cytokines that may contribute to osteoporosis are secreted from visceral fat (8). Therefore, it's crucial to utilize more specific anthropometric measurements to assess body fat distribution alongside BMI.

To address these limitations, specific anthropometric measurements have gained attention from researchers and clinicians to understand better body fat distribution and its impact on health. Indices such as the Waist-to-Hip Ratio (WHR), Waist-to-Height Ratio (WHtR), Conicity Index (C-index), and Visceral Adiposity Index (VAI) have gained prominence for their ability to provide a more distinct assessment of body structure and its relationship with health outcomes, including osteoporosis (9-11). Integrating these advanced anthropometric indices into clinical practice may enhance the identification and management of osteoporosis, particularly in populations with diverse body compositions.

This study aims to evaluate the association between various anthropometric measurements of body fat distribution and the risk of osteoporosis in postmenopausal women. By comparing traditional BMI with alternative indices, we seek to determine which measures provide the most accurate and effective assessment of body composition in relation to osteoporosis risk.

2. Materials and Methods

In this cross-sectional study postmenopausal women age between 45 and 75 years old who visited the gynecology and menopause clinics of tertiary hospital for routine gynecological control were planned to include in study. The study approval was taken from Ankara Etlik City Hospital's review board (AEŞH-BADEK-2024-020). Written and verbal informed consent was taken from the women who were volunteer for participation.

There was 450 volunteer postmenopausal women who underwent DEXA for BMD assessment. Demographic information, medical and obstetric history, and medication usage were collected from questionnaires. Women with the absence of menstruation for at least one year, and availability of recent BMD measurements (within the past year), along with concurrent fasting blood glucose and lipid profiles. After an overnight fast blood samples were drawn in the morning after an examination.

Women with fractures, those with a history of bisphosphonates, estrogen replacement therapy, and glucocorticoids, or a history of malignancy, radiotherapy or chemotherapy, renal failure, hyperthyroidism, primary hyperparathyroidism, rheumatic diseases and adrenal conditions were excluded from the study. Flow chart of the study was shown in Figure 1. A total of 304 postmenopausal women were participated in the study. All measurements were conducted by trained researchers following standardized protocols.

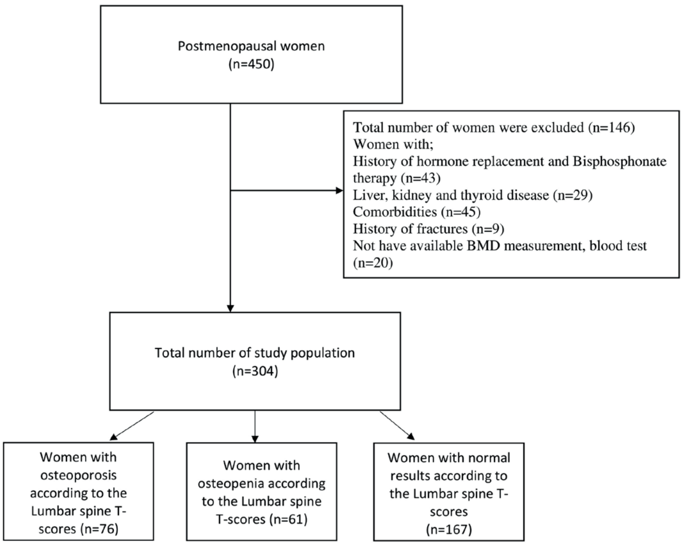

Figure 1. Flow chart of the study

Measurements

1. Anthropometric Measurements:

- **Weight and Height:** Measured using a standard digital scale and stadiometer to the nearest 0.1 kg and 0.1 cm, respectively.
- **Waist Circumference (WC):** Measured at the midpoint between the lowest rib and the iliac crest using a flexible, plastic-coated tape to the nearest 0.1 cm.
- **Hip Circumference (HC):** Measured at the widest part of the hips over the buttocks using the same tape to the nearest 0.5 cm.

2. Body Mass Index (BMI):

- Calculated by dividing weight (kg) by height squared (m^2).

3. Anthropometric Indices:

- **Waist-to-Hip Ratio (WHR):** Calculated by dividing Waist Circumference divided by Hip Circumference.
- **Waist-to-Height Ratio (WHtR):** Calculated by dividing Waist Circumference by height.
- **Conicity Index (C-index):** Calculated as WC (m) divided by [0.109 × body weight (kg) / height (m)] (12).
- **Visceral Adiposity Index (VAI):** Calculated using the formula:
- VAI Female = [36.58+(1.88×BMI) WC (cm)] × (0.81TG) × (HDL-C1.52) where TG is triglycerides, and HDL-C is high-density lipoprotein cholesterol (13).

4. Bone Mineral Density (BMD):

- DEXA scan was used to determine bone mineral density at the lumbar spine and femoral neck. Osteoporosis was defined by a T-score of less than -2.5 SD, osteopenia by a T-score between -1 and -2.5 SD, and normal bone density by a T-score between -1 SD and +1 SD (2).

Statistical analysis

SPSS software version 25.0 (IBM Corp., Armonk, NY) was used for statistical analysis. Descriptive statistics were used to summarize the general characteristics, anthropometric measurement, and laboratory findings of the study population. Continuous variables were presented as means ± standard deviations. To compare the general characteristics, measurements, and laboratory findings among the three groups (normal, osteopenia, and osteoporosis), one-way ANOVA was performed for continuous variables, followed by post hoc Tukey tests for pairwise comparisons. Correlation analysis was used to evaluate the correlation between lumbar spine and femoral neck T-scores and various anthropometric indices, including BMI, WHR, WHtR, and C-index. Pearson correlation coefficients were calculated. To further explore the associations between anthropometric measurements and BMD, multivariate linear regression analyses were performed. Different models were used for lumbar spine and femoral neck T-scores as dependent variables. Receiver Operating Characteristic (ROC) curve analyses were used to assess the predictive ability of different anthropometric indices for identifying osteoporosis. Area under the curve (AUC) values with 95% confidence intervals (CI) were calculated to determine the diagnostic performance of each index. A p-value of <0.05 was considered statistically significant for all tests.

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Table 1. General characteristics, measurements and laboratory results of the patients	
	(N=304)
Age (y)	56.35±5.03
Parity (median,min-max)	2 (0-7)
Fasting Glucose (mg/dL)	110.68±39.8
Triglyceride (mg/dL)	148.62±56.05
Total cholesterol (mg/dL)	199.88±41.74
HDL-cholesterol (mg/dL)	53.99±13.15
LDL- cholesterol (mg/dL)	123.84±34.6
Hip circumference (cm)	110.53±13.85
Waist circumference (cm)	98.64±13.85
BMI (kg/m^2)	30.78±6.38
WHR	0.89±0.08
WHtR	0.63±0.09
Conicity index	0.19±0.02
VAI	5.52±2.93
Lumbar Spine T-score	-0.132±2.99
Femoral Neck T-score	1.24±3.06
BMI: Body mass index, WHR: Waist to hip ratio, WHtR: weight to height ratio, VAI: visceral adipocity index	

3. Results

Table 1 presents the general characteristics, anthropometric measurements, and laboratory findings of the study population. Women were categorized into three groups based on their lumbar spine BMD results: normal, osteopenia, and osteoporosis.

Table 2 provides a detailed comparison of general characteristics, anthropometric measurements, and laboratory findings across the three BMD categories. The VAI values were similar among the three groups ($p > 0.005$). Correlation analysis revealed a positive and moderate correlation between T-scores of lumbar spine ($r = 0.350$, $p < 0.001$) and T-scores of femoral neck ($r = 0.347$, $p < 0.001$) with BMI. A negative and weak correlation was found between lumbar spine ($r = -0.261$, $p < 0.001$) and femoral neck T-scores ($r = -0.307$, $p < 0.001$) with the C-index.

ROC analyses were performed to assess the predictive ability of various indices for identifying osteoporosis. A higher C-index demonstrated predictive ability for determining women with osteoporosis according to lumbar spine T-scores (AUC = 0.722, 95% CI 0.660-0.783) and femoral neck T-scores (AUC = 0.679,

Table 2. Comparison of the groups according to the lumbar spine T-scores				
	Osteoporosis group	Osteopenia group	Normal group	
	(n=76)	(n=61)	(n=167)	p
Age (y)	57.89±4.63^{a}	57.67±4.7^{a,b}	55.16±5.04^{c}	<0.001
Parity (median, min-max)	2(0-6)	2(0-7)	2(0-7)	0.797
Fasting Glucose (mg/dL)	116.97±49.06^{a}	119.9±40.2^{a,b}	104.44±33.64^{c}	0.025
Triglyceride (mg/dL)	156.61±61.93^{a}	160.68±54.12^{a,b}	140.57±52.86^{c}	0.042
Total cholesterol (mg/dL)	205.19±36.61	191.49±40.64	196.89±44.01	0.136
HDL- cholesterol (mg/dL)	57.03±14.14^{a}	50.24±10.83^{b}	53.98±13.18^{a,b}	0.007
LDL- cholesterol (mg/dL)	128.9±32.28^{a}	134.16±36.11^{a,b}	117.6±33.99^{c}	0.004
Hip circumference (cm)	105±10.68^{a}	115.14±16.65^{b}	111.36±12.17^{b,c}	<0.001
Waist circumference (cm)	92.78±11.15^{a}	102.57±16.37^{b}	99.86±13.2^{b,c}	<0.001
BMI (kg/m^2)	27.24±4.83^{a}	33.03±8.12^{b}	31.57±5.64^{b,c}	<0.001
WHR	0.88±0.07	0.89±0.08	0.89±0.08	0.829
WHtR	0.59±0.07^{a}	0.66±0.1^{b}	0.63±0.08^{b,c}	<0.001
Conicity index	0.2±0.01^{a}	0.18±0.01^{b}	0.18±0.01^{b,c}	<0.001
VAI	5.24±2.82	6±3.42	5.48±2.79	0.295
Lumbar Spine T-score	-3.77±0.65^{a}	-1.71±0.34^{b}	2.1±2.03^{c}	<0.001
Femoral Neck T-score	-1.9±0.95^{a}	-0.31±0.59^{b}	3.24±2.67^{c}	<0.001
^{a,b,c} groups with different letters are significantly different from each other. BMI: Body mass index, WHR: Waist to hip ratio, WHtR: weight to height ratio, VAI: visceral adipocity index.				

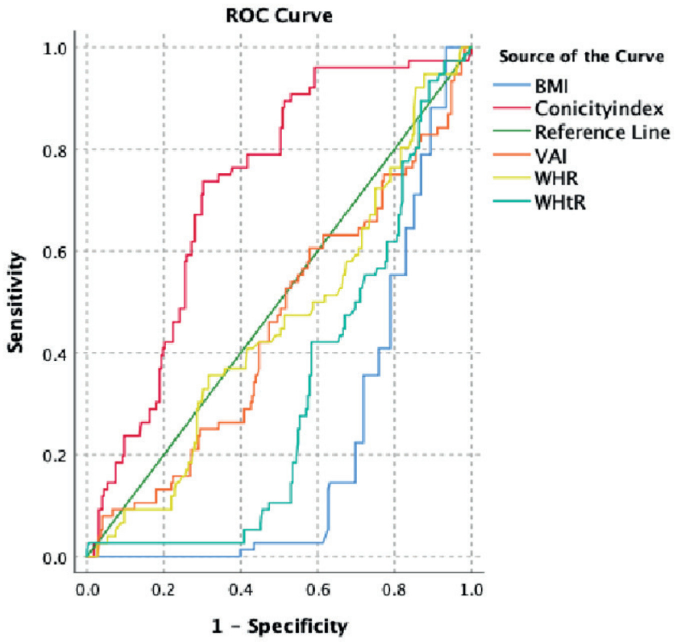

Figure 2. ROC analysis of the anthropometric measurements and osteoporosis according to the Lumbar spine T-scores

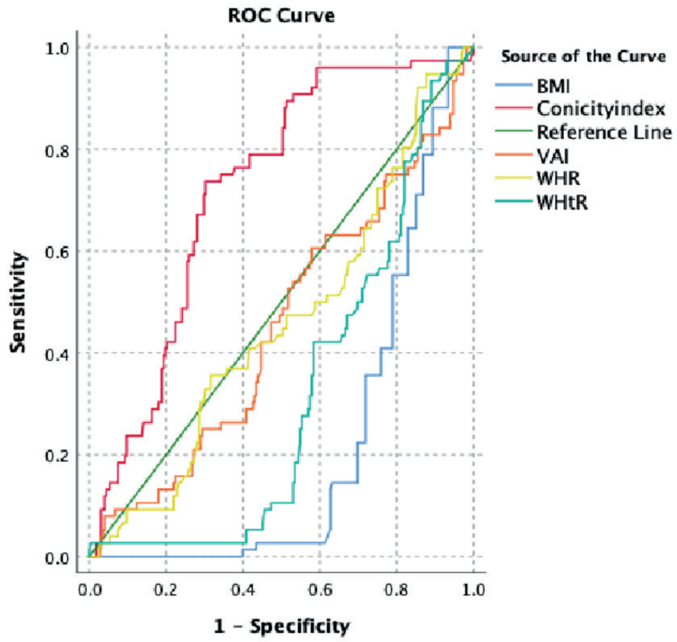

Figure 3. ROC analysis of the anthropometric measurements and osteoporosis according to the femoral neck T-scores

Table 3. Multivariate Linear Regression Analysis of the Measurements and T-Scores

	Lumbar spine T-score				Femoral neck T-score			
			95% CI				95% CI	
	Beta	p	Lower Bound	Upper Bound	Beta	p	Lower Bound	Upper Bound
BMI	.503	.001	3.558	15.403	.413	.004	.075	.380
Weight	-.193	.202	.118	.425	-.298	.044	-.119	-.002
WHtR	-.236	.104	-16.736	1.575	-.189	.182	-15.320	2.929
WHR	.256	.002	-77.454	4.732	.343	.000	7.049	18.854
Conicity index	-.245	.083	-.041	.186	-.455	.001	-110.019	-28.110
VAI	.071	.211	-.097	.021	.092	.096	-.017	.209

BMI: Body mass index, WHR: Waist to hip ratio, WHtR: weight to height ratio, VAI: visceral adipocity index.

95% CI 0.592-0.766). Lower BMI and lower WHtR values were predictive of osteoporosis based on lumbar spine T-scores (BMI AUC = 0.783, 95% CI 0.733-0.833; WHtR AUC = 0.682, 95% CI 0.620-0.743) and femoral neck T-scores (BMI AUC = 0.699, 95% CI 0.630-0.768; WHtR AUC = 0.612, 95% CI 0.518-0.706) (Figure 2 and 3).

In the multivariate linear regression analysis for the lumbar spine T-score model, a positive and significant association was found with BMI (Beta = 0.503, p = 0.001) and WHR (Beta = 0.256, p = 0.002). Similarly, in the femoral neck T-score model, both BMI (Beta = 0.413, p = 0.004) and WHR (Beta = 0.343, $p < 0.001$) showed positive and significant associations. Additionally, a negative and significant association was observed with the C-index (Beta = -0.455, p = 0.001) (Table 3).

4. Discussion

To evaluate the association between various anthropometric measurements and osteoporosis in postmenopausal women was the primary aim of the study. By comparing traditional BMI with alternative indices such as WHR, WHtR, CI, and VAI, we sought to determine which measures provide the most accurate reflection of bone health. Our results indicated that BMI, C-index, and WHtR are significant predictors of osteoporosis.

While BMI and WHR showed a positive association with both lumbar spine and femoral neck T-scores, C-index showed a negative association with femoral neck T-scores.

Fan et al. (14) found that both lean mass (LM) and fat mass (FM) positively correlated with BMD in postmenopausal women, with FM maintaining its positive association even after adjusting for age, height, and years of post-menopause. Their study did not find a significant association between the android-to-gynoid fat ratio (AOI) and BMD, except for the head region. Our results confirm the positive association between WHR and BMD. However, unlike Fan et al., we did not measure AOI, highlighting a difference in our assessment of fat distribution's impact on BMD.

Yaman et al. (15) found that lower weight and BMI were linked to lower T-scores at the lumbar spine and femur in postmenopausal women. They also noted a positive correlation between thigh circumference, skeletal mass index (SMI), and femur T-scores. Our findings align with theirs, showing a positive correlation between BMI and T-scores at the lumbar spine and femoral neck. This supports the idea that higher body weight, often comprising more lean and fat mass, benefits bone health.

Murat et al. (16) found significant correlations between lumbar spine T-scores and skeletal muscle mass index (SMI), weight, BMI, and waist circumference (WC). The correlations between femur neck T-scores and fat percentage, SMI, weight, BMI, WC, and hip circumference were noted in this study. These similar findings with our study highlight the importance of considering multiple anthropometric indices in assessing osteoporosis risk.

The effect of anthropometric factors on osteoporosis which is diagnosed by using different tools was not found association with body weight, BMI, or DXA anteroposterior spine thickness (17). In our study BMI showed a significant positive association with both lumbar spine and femoral neck T-scores. Li et al. (18) found a positive correlation between lean mass and total BMD and a negative correlation with visceral fat mass. These studies support that it is benefical for bone health maintaining an appropriate balance of body composition.

VAI was found independently linked to a higher prevalence of osteoporosis in older people of US (19). Sun et al. (19) found that with each one-unit increase in the VAI, the prevalence of osteoporosis decreased by 1.2%. In contrast, our study found that VAI values did not significantly differ among normal, osteopenia, and osteoporosis groups. This suggests that while VAI is useful for assessing visceral fat and related metabolic risks, it may not be an indicator of osteoporosis risk. This aligns with the understanding that osteoporosis is multifactorial and requires consideration of other factors such as age, hormonal status, and overall nutritional status.

Strengths and limitations

This study has several strengths like a well-defined study population, string inclusion and exclusion criteria. However, there are several limitations. Firstly, the cross-sectional design limits causal inferences, and the study population may not be representative of the general population due to the single center design. Additionally, other factors influencing bone health, such as dietary intake, physical activity, and genetic predispositions, were not controlled for in this study.

5. Conclusion

In conclusion, this study emphasizes the importance of using anthropometric indices with BMI to assess osteoporosis risk in postmenopausal women. The indices such as the C-index, WHR and WHtR provide valuable insights into bone health. This has an importanance for postmenopausal women, who often present with different body compositions that are not adequately captured by BMI alone. Integrating these measurements into clinical practice can improve the identification and prevention of osteoporosis, ultimately reducing morbidity and mortality associated with this condition.

Author contribution

Study conception and design: BK and CK; data collection: BK, CK, SM, and SKE; analysis and interpretation of results: BK, CK, SM, and SKE; draft manuscript preparation: BK, CK, and HLK. All authors reviewed the results and approved the final version of the manuscript.

Ethical approval

The study was approved by the Ankara Etlik City Hospital Scientific Research Evaluation and Ethics Committee (Protocol no. AEŞH-BADEK-2024-020/14.02.2024).

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Conflict of interest

The authors declare that there is no conflict of interest.

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Araştırma fikri ve tasarımı: BK ve CK; veri toplama: BK, CK, SM ve SKE; sonuçların analizi ve yorumlanması: BK, CK, SM ve SKE; araştırma metnini hazırlama: BK, CK ve HLK. Tüm yazarlar araştırma sonuçlarını gözden geçirdi ve araştırmanın son halini onayladı.

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