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# Diagnostic Performance of Advanced Geometric Indices versus Traditional Anthropometric Indices in Evaluating Female Infertility Risk: A Cross-Sectional Study

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# Diagnostic Performance of Advanced Geometric Indices versus Traditional Anthropometric Indices in Evaluating Female Infertility Risk: A Cross-Sectional Study

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## ABSTRACT

**Background:** Infertility impacts reproductive-age couples worldwide, with obesity—especially abdominal obesity—being increasingly recognized as a factor in female reproductive dysfunction. Alternative anthropometric measures beyond body mass index (BMI), such as the body shape index (ABSI), waist–to-hip ratio (WHR), and body adiposity index (BAI), may provide a more complete assessment of body composition related to fertility; however, data directly comparing their discriminatory power in clinical settings remain limited. This study compared anthropometric parameters between fertile and infertile women to understand the relationship between body composition and infertility.

**Methods:** A cross-sectional study was conducted with 210 women divided into fertile (n =105) and infertile (n =105) groups at Konya City Hospital. The fertile participants achieved spontaneous pregnancy without chronic disease, whereas the infertile participants had unexplained infertility or ovulatory dysfunction. Anthropometric measurements were taken, and BMI, WHR, waist-to-height ratio (WHtR), ABSI, body roundness index (BRI), and BAI were calculated. Hormonal parameters and antral follicle counts were obtained for the infertile group.

**Results:** Hip circumference was significantly greater in infertile women ($p = 0.028$), whereas WHR and ABSI were significantly greater in fertile women ($p < 0.001$ for both). BAI was significantly greater in the infertility cohort ($p = 0.007$). In the ROC curve analysis, generalized obesity metrics (BMI, weight, height) and certain central indices (WC, WHtR, BRI) failed to demonstrate discriminative power ($p \geq 0.05$). Conversely, novel and regional geometric indices demonstrated prominent predictive performance; the BAI yielded an AUC of 0.603 (95% CI: 0.527–0.680, $p = 0.010$), with an optimal cutoff of > 33.87. Owing to their inverse physiological distributions, the WHR and ABSI displayed significant inverse discriminative pathways for infertility status, yielding AUC values of 0.319 (95% CI: 0.247–0.491, $p < 0.001$; cutoff $\leq 0.80$) and 0.356 (95% CI: 0.282–0.430, $p < 0.001$; cutoff $\leq 0.076$), respectively.

**Conclusion:** Anthropometric measurements reflecting abdominal fat distribution—particularly the WHR, ABSI, and BAI—show significant associations with infertility beyond traditional BMI assessment. A comprehensive, multidimensional anthropometric evaluation, including multiple indices, is recommended for routine infertility assessment to improve risk stratification and diagnostic guidance.

**Keywords:** Anthropometric Measurements, Fertility, Infertility, Obesity, Body Adiposity Index, Waist-to-Hip Ratio, Body Shape Index

## Background:

Infertility is defined as the absence of a clinical pregnancy despite at least one year of regular, unprotected sexual intercourse. Infertility affects approximately 10%-15% of couples worldwide [1,2]. The etiology of female infertility is multifaceted, predominantly encompassing tubal and pelvic factors (35%), male factors (35%), and ovulatory dysfunction (15%), whereas cases with no identifiable cause after comprehensive diagnostic workup are classified as unexplained infertility (15%) [3,4]. Together, ovulatory dysfunction and unexplained infertility constitute nearly half of all female infertility cases, many of which are increasingly linked to the global epidemic of obesity [5,6]. Excessive adiposity is caused by chronic low-grade inflammation, peripheral insulin resistance, and functional hyperandrogenism, which synergistically impair the hypothalamic–pituitary–ovarian axis and disrupt normal ovulatory function [7-11]. Furthermore, contemporary epidemiological and Mendelian randomization analyses substantiate a causal relationship between visceral fat accumulation and reproductive disorders, which is mediated through distinct metabolic and endocrine pathways [12].

Although body mass index (BMI) remains the conventional gold standard for diagnosing and classifying obesity in clinical practice, it has profound limitations in distinguishing between lean mass and adipose tissue, and it fails to capture visceral fat distribution or body fat localization [13]. Consequently, individuals with identical BMI values can present markedly disparate body compositions, peripheral fat allocations, and associated metabolic risk profiles. To overcome these limitations, alternative anthropometric indices have been developed, including waist circumference (WC), the waist–hip ratio (WHR), the waist–to–height ratio (WHtR), the body roundness index (BRI), the body adiposity index (BAI), and the body shape index (ABSI) [14-16]. Contemporary epidemiological and genetic analyses strongly substantiate the causal relationship between these visceral fat allocations and female reproductive conditions. Specifically, recent Mendelian randomization analyses by Wu et al. have demonstrated a direct, genetically driven causal link between elevated WHR and increased risk of female reproductive disorders [17]. Furthermore, population data from the National Health and Nutrition Examination Survey (NHANES) revealed that central adiposity indices outperform traditional BMI in predicting female infertility risk [16]. Wen and Li reported a strong positive linear association between the weight-adjusted waist index (WWI) and increased odds of infertility [18]. Similarly, Zhuang et al. reported that the visceral adiposity index (VAI) serves as a powerful independent predictor of female reproductive impairment [19]. In terms of geometric body mapping, Gong et al. established a significant positive association where elevated body roundness index (BRI) values correspond with substantially heightened infertility odds, yielding an area under the curve (AUC) of 0.618 [20]. Concurrently, Yang

et al. confirmed that an advanced ABSI threshold is directly intertwined with increased female infertility risk within large-scale cross-sectional populations [21].

Despite the emerging evidence from large-scale database registries, clinical validation directly comparing the discriminatory ability of these novel anthropometric metrics against traditional BMI in well-defined patient cohorts remains scarce. Given that body fat distribution and its metabolic consequences can exhibit significant ethnic and regional variations, clinical data from localized prospective or cross-sectional cohorts are crucial for implementing these indices in routine gynecological practice.

On the basis of recent evidence highlighting the superior predictive utility of visceral adiposity over generalized obesity, we hypothesized that novel indices such as the WHR, ABSI, BRI, and BAI would demonstrate stronger and more clinically relevant associations with female infertility than traditional BMI. Accordingly, this study aims to comprehensively compare these anthropometric parameters between fertile and infertile women within a specialized tertiary care setting, evaluating their potential clinical utility as noninvasive screening tools in routine fertility assessments.

## Methods:

### Study Design and Population Setting

This cross-sectional, observational, analytical study was conducted at the Obstetrics and Gynecology Outpatient Clinic of Konya City Hospital between July 2024 and January 2025. The study population comprised 210 women divided into two parallel groups: an infertile group (n=105) and a healthy, fertile control group (n=105). All participants provided written informed consent prior to enrollment.

An *a priori* power analysis was conducted via G*Power 3.1.9 [22] to determine the minimum sample size required for independent sample *t* tests to compare anthropometric indices between fertile and infertile women. Given the absence of prior studies that compared the waist-to-height ratio (WHtR), body adiposity index (BAI), body roundness index (BRI) and body shape index (ABSI) simultaneously in the context of female infertility, we adopted a medium effect size ($d = 0.5$) on the basis of Cohen's conventions [23]. This approach is endorsed by contemporary methodological guidance when domain-specific effect size estimates are unavailable [24,25]. With a two-tailed alpha level of 0.05 and a desired power ($1 - \beta$) of 0.95, the analysis indicated a minimum of 104 participants per group. Accordingly, 105 fertile women and 105 infertile women were enrolled ($N = 210$), fully satisfying the sample size requirement. Sensitivity analysis confirmed that this sample size also provides at least 80% power to detect smaller effect sizes ($d = 0.43$) at the same alpha level, ensuring adequate statistical sensitivity for the study.

**Inclusion and exclusion criteria**: To ensure a highly homogeneous cohort, strict selection criteria were applied.

- The inclusion criteria for the fertile group were women aged 18--38 years who achieved spontaneous natural pregnancy, regardless of the ultimate gestational outcome, and presented with no known chronic metabolic, systemic, or endocrine diseases.
- The inclusion criteria for the infertile group were as follows: women aged 18 to 38 years with primary infertility, presenting with no previous history of pregnancy, who met the diagnostic criteria for either unexplained infertility (ability to conceive after 12 months of regular, unprotected intercourse with confirmed bilateral tubal patency, normal semen parameters, and regular ovulatory cycles) or ovulatory dysfunction (including anovulation, polycystic ovary syndrome [PCOS], and hypogonadotropic hypogonadism).
- The exclusion criteria (both groups*)* were as follows: women with known endocrine comorbidities such as uncompensated thyroid dysfunction or hyperprolactinemia; infertility documented as secondary to male factors or anatomical tubal obstructions; and pregnancies or fertility treatments achieved through assisted reproductive technologies (ART).

**Anthropometric Measurements and Index Calculations**: All anthropometric dimensions were gathered by a single trained examiner using identical equipment to prevent interexaminer variability, with participants measured after an 8-hour overnight fast. The participants stood barefoot in lightweight clothing, and their weight and height were recorded to the nearest 0.1 kg and 0.1 cm, respectively. Waist circumference was measured at the end of a normal expiration at the narrowest zone midway between the lower costal margin and the iliac crest. Finally, the hip circumference was measured horizontally at the point of maximum gluteal extension.

These primary metrics were utilized to calculate established and novel anthropometric indices via the following standardized formulas:

Body mass index (BMI): Body mass in kilograms divided by the square of height in meters ($kg/m^2$)

Waist-to-height ratio (WHtR)**:** The ratio of waist perimeter (cm) divided by total stature (cm)

Waist-to-hip ratio (WHR): Dividing waist circumference by hip circumference

A Body shape index (ABSI): WC (m)/[ $(BMI)^{2/3} \times (height\ (m))^{1/2}$ ] [14].

Body roundness index (BRI): This index is computed through the geometric eccentricity equation= $364.2 - 365.5 \times \sqrt{1 - \left(\frac{WC}{2\pi}\right)^2 \div \left(\frac{Height}{2}\right)^2}$ [15].

Body adiposity index (BAI)**:** Stimated via the specialized equation $= \frac{\text{HC (cm)}}{\text{Height (m)}^{1.5}}$ -18 [13].

A detailed sociodemographic and reproductive history—including parity, obstetric history, lifestyle habits (smoking and alcohol consumption), educational attainment, and partner characteristics—was systematically documented. For the infertile group, luteinizing hormone (LH), follicle-stimulating hormone (FSH), and estradiol (E2), which were assessed during 2–3 days of the menstrual cycle, were taken from the hospital's electronic health records. Baseline transvaginal ultrasonography was performed for the infertile group via the same equipment to document total antral follicle counts (AFCs) across both ovaries in the early follicular phase. No additional venipunctures or diagnostic imaging interventions were performed specifically for the purpose of this study.

**Statistical analysis**

Data distribution profiles across the study cohorts were formally evaluated via the Kolmogorov–Smirnov test in conjunction with visual histogram inspections to ascertain normality. Continuous metrics demonstrating parametric characteristics are expressed as the mean values accompanied by standard deviations ($\bar{x} \pm SD$). Conversely, variables with nonnormally distributed patterns were documented via medians and corresponding interquartile ranges [Med. (IQR)]. Fractional data and categorical distributions are presented as absolute counts along with percentage values ($n, \%$).

To analyze variations between the parallel groups, independent-samples $t$ tests were deployed for normally distributed continuous vectors, whereas the Mann–Whitney $U$ test was reserved for evaluating nonparametric metric strings. Discrepancies among categorical arrangements and proportional distributions were calculated via chi-square ($\chi^2$) tests. In instances where minimum cell frequency assumptions were violated owing to zero values in the demographic submatrices, Fisher's exact tests were executed to ensure exact probability values. Continuous relationships and explanatory correlation trajectories between the calculated regional adiposity indices and specific biochemical, clinical, or obstetric markers were investigated. Depending on the data distribution profiles and metric structures evaluated via normality tests, bivariate correlation patterns were quantified via either the Pearson product–moment correlation coefficient ($r$) for parametric data sequences or the Spearman rank correlation coefficient ($r_s$) for nonparametric continuous strings. Statistical computations were conducted via standard commercial software, and a two-tailed $p$ value of less than 0.05 was mandated to establish statistical significance.

**Ethical approval** The study protocol was approved by the Institutional Review Board/Local Ethics Committee of the Karatay University Non-Pharmaceutical and Medical Device Research Ethics

Committee (Decision Date: 28.06.2024, Approval Number: 2024/027). The study was conducted in strict accordance with the ethical principles of the Declaration of Helsinki.

**Results**:

**Demographic and baseline characteristics**

A total of 210 women completed the study and were divided into an infertility group (n = 105) and a fertile control group (n = 105). There were no statistically significant differences between the infertile and fertile groups in terms of maternal age (28.08 ± 4.8 vs. 29.05 ± 4.7 years, respectively; p = 0.142), educational background *(*p = 0.733), or smoking prevalence (p = 0.837). Similarly, paternal smoking status (p = 0.776) and daily cigarette pack consumption (p = 0.630) did not differ significantly between the two groups, confirming baseline homogeneity. With respect to obstetric background, a highly significant difference was observed in parity status ($p < 0.001$). By clinical definition, the entire infertile cohort was nulliparous (100.0%), whereas the fertile control group was predominantly composed of multiparous women (89.5%, $n = 94$), with a small subset of nulliparous individuals who had a history of early pregnancy loss (10.5%, $n = 11$). The detailed sociodemographic and obstetric features of the study population are comprehensively documented in Table 1.

**Comparison of Traditional and Novel Anthropometric Measurements**

A comparison of traditional and alternative anthropometric parameters between the groups is presented in Table 2. No significant differences in height (p = 0.328), total body weight (p = 0.438), conventional BMI (26.90 ± 5.70 vs. 25.98 ± 4.50 kg/m²; p = 0.196), waist circumference (p = 0.263), or waist–to-height ratio (WHtR) (p = 0.382) were detected between infertile and fertile women.

In contrast, body composition measurements reflecting distinct regional adipose tissue distribution patterns revealed highly significant differences. The total hip circumference was significantly greater in infertile women than in fertile controls (108.29 ± 12 vs. 104.56 ± 12 cm, $t = 2.212$, $p = 0.028$). Conversely, the waist–to-hip ratio (WHR) was significantly lower in the infertile grou*p* than in the fertile group (0.79 ± 0.06 vs. 0.84 ± 0.13, $t = -3.917$, $p < 0.001$). The body shape index (ABSI) followed a similar inverse trajectory, with significantly attenuated values in the infertile cohort compared with those in the fertile control cohort (0.075 ± 0.005 vs. 0.078 ± 0.007, $t = -3.777$, $p < 0.001$). Conversely, the body adiposity index (BAI) was significantly greater in infertile individuals than in the fertile reference population (35.11 ± 6.14 vs 32.86 ± 5.80, $t = 2.733$, p = 0.007).

To assess and compare the diagnostic and discriminative capacities of traditional and modern anthropometric indicators in formally determining female fertility status, a comprehensive receiver operating characteristic (ROC) curve analysis was executed for all ten investigated metrics (Table 3,

Figure 2). Traditional generalized obesity parameters, including height (AUC = 0.470, 95% CI: 0.392–0.549, p = 0.456), weight (AUC = 0.523, 95% CI: 0.445–0.602, p = 0.563), and BMI (AUC = 0.540, 95% CI: 0.461–0.619, p = 0.317), were not significantly different between the cohorts. Similarly, waist circumference (AUC = 0.445, p = 0.166), hip circumference (AUC = 0.575, p = 0.059), WHtR (AUC = 0.455, p = 0.262), and BRI (AUC = 0.455, p = 0.261) failed to demonstrate prominent diagnostic utility.

In contrast, specialized geometric and regional adiposity indices demonstrated statistically prominent performance profiles. The body adiposity index (BAI) achieved a significant positive discriminative efficiency with an AUC of 0.603 (95% CI: 0.527–0.680, p = 0.010), establishing an optimal diagnostic cutoff threshold of >33.87 (sensitivity: 55.8%, specificity: 58.5%). Intriguingly, because the waist-to-hip ratio (WHR) and body shape index (ABSI) values were inherently higher within the fertile control cohort, their raw ROC pathways presented a significant inverse predictive configuration for infertility status ($p < 0.001$ for both). The WHR demonstrated an AUC of 0.319 (95% CI: 0.247–0.491, $p < 0.001$), identifying an optimal discriminative threshold of $\leq 0.80$ (sensitivity: 64.0%, specificity: 60.0%). Concurrently, the ABSI demonstrated an AUC of 0.356 (95% CI: 0.282–0.430, $p < 0.001$), revealing an optimal cutoff of $\leq 0.076$ (sensitivity: 60.0%, specificity: 58.0%). Pairwise evaluation via the nonparametric DeLong test verified that the diagnostic performance pathways of the WHR, ABSI, and BAI were statistically superior to those of traditional BMI configurations in distinguishing clinical fertility dynamics.

**Bivariate correlation profiles in the clinical context**

In the infertile cohort, bivariate evaluation revealed selective, low-level negative correlations between markers of generalized or abdominal fat accumulation and key circulating early-follicular endocrine parameters (Table 4). Total maternal body weight was significantly and inversely correlated with baseline serum LH (r = -0.197, p = 0.044) and $E_2$ *l*evels (r = -0.218, p = 0.026). Similarly, standard BMI (r = -0.198, p = 0.043), isolated waist circumference (r = -0.193, p = 0.049), and WHtR (r = -0.198, p = 0.043) were significantly negatively correlated with circulating LH concentrations. Furthermore, the nonparametric body roundness index (BRI) was significantly negatively correlated with early follicular phase LH values (r = -0.199, p = 0.042). Serum $E_2$ concentrations also demonstrated a separate, significant inverse correlation with maternal waist circumference (r = -0.197, p = 0.044). No statistically significant correlations were established between any anthropometric index and serum FSH levels within the infertile group ($p > 0.05$).

In the healthy, fertile control population, regional body composition patterns revealed significant, low-level positive correlations with long-term reproductive outcomes (Table 5). The total cumulative number of pregnancies was significantly and positively correlated with maternal waist circumference ($r_s = 0.233$, p = 0.022), WHtR ($r_s = 0.214$, p = 0.028), and WHR ($r_s = 0.206$, p = 0.035). Moreover, the nonparametric

BRI was significantly and positively correlated with both the total number of pregnancies ($r_s = 0.255$, $p = 0.009$) and absolute parity ($r_s = 0.199$, $p = 0.042$). Maternal WHtR also maintained a direct positive relationship with cumulative parity ($r_s = 0.199$, $p = 0.042$). No anthropometric parameters evaluated within the fertile group were significantly correlated with the overall historical frequency of miscarriages ($p > 0.05$).

**Discussion:**

The findings of this cross-sectional study demonstrate that contemporary anthropometric indices reflecting visceral and regional adiposity distributions have significant clinical utility in differentiating between fertile and infertile women, markedly outperforming conventional body mass index (BMI) assessments. While generalized obesity indices such as body weight and BMI did not significantly differ between the two cohorts, indicators of body fat localization—specifically, the body shape index (ABSI), hip circumference (HC), waist–hip ratio (WHR), and body adiposity index (BAI)—showed pronounced differences. These results strongly reinforce the paradigm that regional adipose allocation and metabolic topography exert a more profound impact on female reproductive physiology than does total body mass alone.

Our observed clinical trends align substantially with, yet uniquely complement, recent large-scale epidemiological investigations and genetic causal analyses. Recent comprehensive studies have robustly explored the intricate relationships between various alternative anthropometric indices and female reproductive failure. Specifically, Gong et al. demonstrated that the body roundness index (BRI) can predict infertility with an AUC of 0.618 within a large NHANES cohort, whereas Zhuang et al. reported a significant risk trajectory for the visceral adiposity index (VAI) with an odds ratio of 1.22 (95% CI: 1.03--1.45) (19,20). Furthermore, Wen and Li confirmed that the weight-adjusted waist index (WWI) has a distinct, independent positive relationship with female infertility risk, outperforming conventional metrics [18]. In the context of advanced geometric parameters, Yang et al. documented a direct correlation between elevated ABSI thresholds and increased infertility profiles [21]. Providing the strongest causal foundation, the landmark Mendelian randomization study by Wu et al. revealed a direct genetic causal link between abdominal fat distribution, measured via the waist–to-hip ratio (WHR), and anovulatory infertility pathways [17]. Remarkably, while the BRI in our localized cohort did not reach independent diagnostic significance (AUC = 0.455), our BAI results demonstrated highly comparable and significant discriminative efficiency (AUC = 0.603, $p = 0.010$), indicating that it was the most successful next-generation adiposity parameter in our study. This finding is also consistent with that of Zhao et al., who reported that the Conicity Index (C-index) showed similar diagnostic efficacy (AUC = 0.608) in determining infertility risk via NHANES data ([26]). While these database registries provide invaluable macroscopic evidence, they rely entirely on

self-report questionnaire responses and represent broad epidemiological screens [18–21]. In contrast, our current investigation provides essential clinical validation within a well-defined cohort in a tertiary healthcare setting, demonstrating that while broad populations show direct positive risk lines, specific clinical cohorts may display inverse local variations—such as our observed inverse WHR and ABSI trajectories—due to structural maternal remodeling and parity history.

However, the results of our study revealed that, contrary to the general trend reported in the literature, the waist–to–hip ratio (WHR) (0.84 +/- 0.13) and ABSI (0.078 +/- 0.007) values were significantly greater in the fertile group than in the infertile group ($p < 0.001$). This 'morphological deviation' was demonstrated by Mamun et al. and Gunderson et al. and can be explained by the permanent 'maternal remodeling' effect of birth on female anthropometry [27,28]. According to these studies, a successful pregnancy process leads to permanent and cumulative increases in waist circumference due to the expansion of the abdominal muscles, the growth of the uterus, and the shift of fat storage to the trunk area. Therefore, the high WHR and ABSI values in the fertile group may reflect permanent traces of reproductive success in terms of female anatomy rather than a basal obesity state. A 27-year prospective study conducted by Mamun et al. revealed that weight gain during pregnancy increases the risk of abdominal obesity by 3.09 times even approximately three decades after childbirth, leading to permanent enlargement around the waist [27]. This explains why the fertile women in our study had higher central adiposity measurements as a biological consequence of parity.

Infertile women, the absolute hip circumference (HC) and BAI indicators were greater. This morphological difference can be explained through several integrated biological pathways. First, the relationship between adipose tissue geometry and reproductive outcomes can follow a complex and nonlinear distribution, as confirmed by Gong et al., who demonstrated that the BRI follows a nonlinear trajectory in its association with infertility risk [20]. Second, higher BAI and hip measurements with reduced WHR in the infertile group indicate a distinct peripheral or gluteofemoral fat storage phenotype. Gluteofemoral fat stores have different lipolytic and adipokine release patterns than visceral fat stores do; in cohorts with ovulatory phenotypes or unexplained infertility profiles, such as PCOS, this regional fat distribution may be closely linked to hyperinsulinemia or metabolic characteristics without classic android obesity and may uniquely affect the oocyte microenvironment [29,30]. The specific physiological mechanisms involved in reproductive dysfunction in individuals with central obesity involve intricate endocrine and metabolic signaling networks. Central metabolic disorders and increased visceral fat load are directly linked to polycystic ovary syndrome (PCOS) phenotypes and subsequent anovulatory cycles [9,12].

The finding that early follicular phase luteinizing hormone (LH) and estradiol (E2) concentrations detected in our infertile cohort were significantly negatively correlated with maternal weight, BMI,

waist circumference, and body roundness index (BRI) ($p < 0.05$) clinically confirms the suppressive effect of progressive peripheral and abdominal fat accumulation on the neuroendocrine axis [17,31]. Consistent with the literature, visceral adipose tissue functions as an active endocrine organ that triggers chronic low-grade systemic inflammation and insulin resistance, suppresses sex hormone-binding globulin (SHBG) levels, and paves the way for functional hyperandrogenism [6,9,17,31]. Furthermore, prospective cohort data from the EAGeR study by Bloom et al. revealed that maternal adiposity parameters significantly predict anovulatory clinical presentations independently of serum free testosterone levels, confirming that adipokine-mediated hypothalamic–pituitary–ovarian (HPO) axis dysfunction is the key pathophysiological pathway [31]. Mendelian randomization analysis performed by Wu et al. further confirmed at the genetic level that the abdominal fat distribution (WHR) directly and causally disrupts neuroendocrine regulation, thereby impairing the oocyte microenvironment [17]. As a result, this progressive hormonal suppression represents the core pathophysiological mechanism through which central obesity impairs gonadotropin secretion and physiological follicle development.

Most importantly, the positive correlations documented within our fertile control group between central adiposity measures (such as waist circumference, WHtR, WHR, and BRI) and long-term reproductive outputs—specifically total numbers of pregnancies and parity—likely mirror permanent mechanical and physiological alterations secondary to gestational history rather than baseline prepregnancy somatotypes [32]. Previous longitudinal data have shown that pregnancy and subsequent childbirth induce a permanent 'maternal remodeling' effect characterized by persistent expansion of the pelvic girdle, alterations in abdominal muscle tone, and a shift toward visceral fat deposition postpartum [28,32]. Therefore, the significantly higher WHR and ABSI profiles observed in our fertile group should be interpreted as a physiological consequence of historical parity and previous successful gestations rather than a baseline risk factor for reproductive failure.

The clinical implications of these findings are substantial for modern reproductive medicine. The incorporation of multidimensional, noninvasive indices such as HC, ABSI, and BAI into routine diagnostic screening algorithms would dramatically optimize risk stratification for infertile couples, enabling the identification of metabolic vulnerabilities in women who present with a normal-range BMI [33]. Identifying these patterns early is crucial, given that metabolically healthy obesity phenotypes can still carry a significantly elevated risk of infertility, as established by Tang et al.[33]. Tailored preconception lifestyle modifications and targeted visceral fat reduction strategies should be deployed aggressively [34]. Furthermore, while elevated maternal adiposity significantly compromises assisted reproductive technology (ART) outcomes, advanced weight management and multidisciplinary counseling should be utilized as tools for preconception optimization rather than as arbitrary barriers to withholding necessary fertility treatments [35].

**Strengths and Limitations**

This study has several methodological and clinical strengths that increase the validity and clinical applicability of its findings. First, this research represents a rare clinical study that simultaneously evaluates and directly compares six anthropometric indices, including traditional (BMI, WC, WHtR) and advanced geometric (ABSI, BRI, BAI) metrics, within a well-defined cohort. Second, a strict, rigorous patient selection protocol was implemented to ensure a highly homogeneous cohort, effectively excluding confounding factors such as male-induced infertility or anatomical tubal obstructions. Furthermore, all anthropometric measurements were performed after an overnight fast by a single trained clinical observer using identical equipment, thus completely eliminating interobserver variability and measurement bias. Despite these strengths, some limitations must be acknowledged. Owing to the cross-sectional architecture of the study, establishing direct temporal or causal relationships between the new anthropometric indices and the onset of reproductive failure is inherently impossible. Additionally, because there was no clinical or ethical indication for routine fertility research in the healthy control group, baseline hormonal parameters and the AFC were not available for the fertile cohort, restricting our ability to perform comparative neuroendocrine correlation analyses between the two parallel groups. The lack of direct gold-standard imaging modalities, such as computed tomography (CT) or magnetic resonance imaging (MRI), has restricted our capacity to quantify visceral and subcutaneous fat volumes directly. Moreover, as a single-center study conducted in a specific tertiary care hospital, the absolute generalizability of optimal diagnostic thresholds and cutoff values may be limited across broader ethnic and geographic demographics. Finally, direct measurements of homeostatic metabolic parameters, such as fasting insulin, glucose, or specialized adipokine profiles, were not available for inclusion. Future large-scale, multicenter prospective validation studies involving direct visceral imaging and dynamic metabolic screening are necessary to confirm the longitudinal stability and optimal diagnostic thresholds of these new indices in fertility planning.

**Conclusion:**

In conclusion, this study demonstrated that advanced geometric anthropometric indices—specifically the body adiposity index (BAI), body shape index (ABSI), and hip circumference (HC)—possess superior clinical utility in distinguishing female fertility profiles compared with the conventional body mass index (BMI). Traditional, generalized markers of obesity fail to capture the subtle variations in visceral and regional fat distributions that are intrinsically linked to neuroendocrine and reproductive dysfunction. Our findings indicate that a distinct, nonandroid regional adiposity phenotype, characterized by increased hip circumference and elevated BAI values, is strongly intertwined with

anovulatory configurations and infertility. Conversely, central adiposity metrics in fertile women appear to be permanently modified by reproductive history and parity rather than baseline metabolic traits. Incorporating these multidimensional, noninvasive indices into routine gynecological screening algorithms would significantly optimize risk stratification, allowing clinicians to detect metabolic vulnerabilities even in patients with a normal-range BMI. Early implementation of tailored preconception weight management and lifestyle optimization is crucial to enhance overall reproductive potential. Ultimately, large-scale, prospective multicenter validation trials incorporating direct visceral imaging are needed to establish accurate, population-specific diagnostic thresholds for these novel metrics in reproductive counseling.

## Declarations

**Abbreviations: BMI:** Body mass index; **WHtR:** Waist-to-height ratio; **WHR:** Waist-to-hip ratio; **ABSI:** Body shape index; **BRI:** Body roundness index; **BAI:** Body adiposity index

**Ethical approval** The study protocol was approved by the Institutional Review Board/Local Ethics Committee of the Karatay University Non-Pharmaceutical and Medical Device Research Ethics Committee (Decision Date: 28.06.2024, Approval Number: 2024/027). The study was conducted in strict accordance with the ethical principles of the Declaration of Helsinki.

**Availability of data and materials**: The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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## TABLES AND FİGURES

**Table** 1 Comparison of demographic characteristics between infertile and fertile women (N=210)

| Demographic Characteristics | | **Infertile Group (n = 105)** **n (% )** | **Fertile Group (n = 105)** **n (% )** | **Statistical Analysis** $\chi^2$ | **p*** |
|---|---|---|---|---|---|
| Education level | Primary School | 7 (6.7) | 11 (10.5) | 1.285 | 0.733 |
| | Middle school | 35 (33.3) | 30 (28.6) | | |
| | High school | 20 (19.0) | 20 (19.0) | | |
| | University | 43 (41.0) | 44 (41.9) | | |
| Smoking status | Yes | 13 (12.4) | 14 (13.3) | 0.043 | 0.837 |
| | No | 92 (87.6) | 91 (86.7) | | |
| Partner smoking | Yes | 66 (62.9) | 64 (61.0) | 0.081 | 0.776 |
| | No | 39 (37.1) | 41 (39.0) | | |
| Gravidity,n(%) | Nulligravida | 105(100.0) | 0 | | |
| | Multigravida | 0 | 105(100) | | |
| Parity,n(%) | Nulliparous | 105(100.0) | 11(10.5) | | **0.001** |
| | Multiparous | 0 | 94(89.5) | | |
| | | **N=105** | **N=105** | **t** | **p**** |
| Age (Years) | $\bar{x} \pm SS$ | 28.08 ± 4.80 | 29.05 ± 4.74 | -1.475 | 0.142 |
| | | **N=13** | **N=14** | **Z** | **p***** |
| Daily pack Consumption | Med. (IQR.) | 0.50 (0.38-0.50) | 0.50 (0.44-1.00) | -0.482 | 0.630 |
| | | **N=66** | **N=64** | **t** | **p**** |
| Partner's Daily Pack | $\bar{x}$±SS | 0.93±0.42 | 0.91±0.42 | 0.360 | 0.720 |

**Abbreviations: SD:** standard deviation; $\chi^2$**:** Chi-square test value; **t:** Independent samples t test value; **Z**: Mann–Whitney U test Z value; **Med. (IQR. ):** Median and interquartile range (25th–75th percentiles; **p:** Statistical significance value (**p** <0.05 is considered statistically significant).

Table 2 Comparison of Anthropometric Measurements between Fertile and Infertile Women

| **Anthropometric Measurements** | | **Infertile Group (N=105)** | **FertileGroup (N=105)** | **t/Z** | **p*** |
|---|---|---|---|---|---|
| Height (m) | x ± ss | 1.61 ± 0.06 | 1.62 ± 0.06 | -0.980 | 0.328 |
| Weight (kg) | x ± ss | 69.75 ± 15.72 | 68.17 ± 13.58 | 0.778 | 0.438 |
| BMI (kg/m²) | x ± ss | 26.90 ± 5.70 | 25.98 ± 4.50 | 1.297 | 0.196 |
| WC (cm) | x ± ss | 85.25 ± 12.90 | 87.17 ± 11.90 | -1.123 | 0.263 |
| WHtR (cm/cm) | x ± ss | 0.53 ± 0.08 | 0.54 ± 0.07 | -0.875 | 0.382 |
| HC (cm) | x ± ss | 108.29 ± 12 | 104.56 ± 12 | 2.212 | **0.028** |
| WHR (cm/cm) | x ± ss | 0.79 ± 0.06 | 0.84 ± 0.13 | -3.917 | **<0.001** |
| ABSI | x ± ss | 0.075 ± 0.005 | 0.078 ± 0.007 | -3.777 | **<0.001** |
| BRI | Med. (IQR) | 3.87 (2.88-4.90) | 3.85 (3.19-5.50) | 1.124 | 0.261 |
| BAI | x ± ss | 35.11 ± 6.14 | 32.86 ± 5.80 | 2.733 | **0.007** |

**Abbreviations: BMI:** Body mass index; **WHtR:** Waist-to-height ratio; **WHR:** Waist-to-hip ratio; **ABSI:** Body shape index; **BRI:** Body roundness index; **BAI:** Body adiposity index; **IQR:** Interquartile range; **SD:** Standard deviation; **t:** Independent samples t test value; **z**: Mann–Whitney U test Z value; **p:** Statistical significance value (< 0.05) is considered statistically significant.

**Table 3** ROC analysis results for hip circumference, waist–to–hip ratio, body shape index, and body adiposity index in predicting fertility status

| Anthropometric Measurements | Area Under the Curve | Standard Error | p | 95% Confidence Interval | | Cutoff Value | Sensitivity | Specificity |
|---|---|---|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound | | | |
| Traditional & Generalized Metrics | | | | | | | | |
| Height (m) | 0.470 | 0.040 | 0.456 | 0.329 | 0.549 | — | — | — |
| Weight (kg) | 0.523 | 0.040 | 0.563 | 0.445 | 0.602 | — | — | — |
| BMI (kg/m²) | 0.540 | 0.040 | 0.317 | 0.461 | 0.619 | — | — | — |
| Central Adiposity & Geometric Indices | | | | | | | | |
| WC (cm) | 0.445 | 0.040 | 0.166 | 0.367 | 0.523 | — | — | — |
| HC (cm) | 0.575 | 0.039 | 0.059 | 0.498 | 0.653 | — | — | — |
| WHR | 0.319 | 0.037 | **<0.001** | 0.247 | 0.491 | ≤ 0.80 | 64.0% | 60.0% |
| WHtR(cm/cm) | 0.455 | 0.040 | 0.262 | 0.377 | 0.533 | — | — | — |
| ABSI | 0.356 | 0.038 | **<0.001** | 0.282 | 0.430 | ≤ 0.076 | 60.0% | 58.0% |
| BRI | 0.455 | 0.040 | 0.261 | 0.377 | 0.533 | — | — | — |
| BAI | 0.603 | 0.039 | **0.010** | 0.527 | 0.680 | > 33.87 | 55.8% | 58.0% |

**Abbreviations: BMI:** Body mass index; **WHtR:** Waist-to-height ratio; **WHR:** Waist-to-hip ratio; **ABSI:** Body shape index; **BRI:** Body roundness index; **BAI:** Body adiposity index; **ROC:** Receiver operating characteristic; **AUC:** Area under the curve; **CI:** Confidence interval; **p:** Statistical significance value ($p < 0.05$ is considered statistically significant).

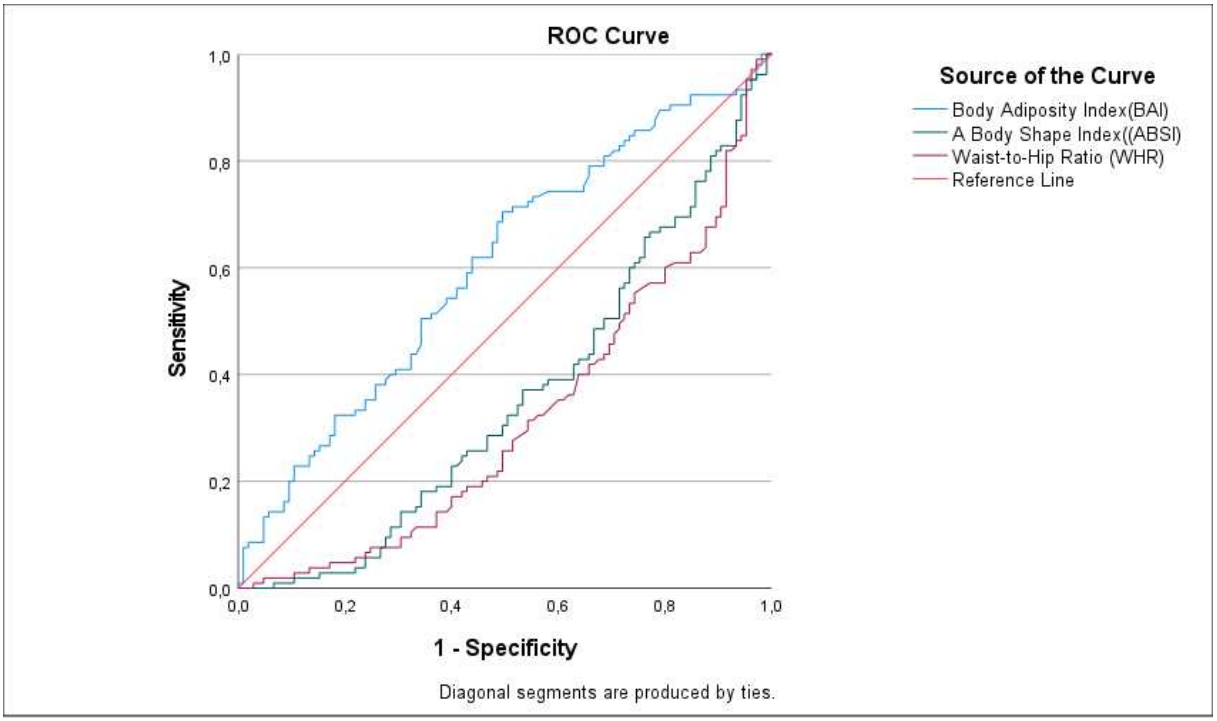



**Figure 2**. ROC curves for the ability of the waist–to-hip ratio, body shape index, and body adiposity index to predict fertility status

**Table 4** Relationships between Anthropometric Measurements and FSH, LH, and E2 Levels in Infertile Women (N=105)

| Anthropometric Measurements (Infertile Women) | **FSH** | | **LH** | | **E2** | |
|---|---|---|---|---|---|---|
| | **r** | **p** | **r** | **p** | **r** | **p** |
| Height (m) | -0.080 | 0.416 | -0.019 | 0.845 | -0.118 | 0.230 |
| Weight (kg) | -0.115 | 0.241 | -0.197 | **0.044** | -0.218 | **0.026** |
| BMI (kg/m²) | -0.087 | 0.375 | -0.198 | **0.043** | -0.187 | 0.057 |
| Waist Circumference (cm) | -0.126 | 0.200 | -0.193 | **0.049** | -0.197 | **0.044** |
| WHtR (cm/cm) | -0.119 | 0.226 | -0.198 | **0.043** | -0.188 | 0.055 |
| Hip Circumference (cm) | -0.123 | 0.210 | -0.164 | 0.094 | -0.166 | 0.091 |
| WHR (cm/cm | -0.091 | 0.355 | -0.158 | 0.107 | -0.171 | 0.082 |
| ABSI | -0.125 | 0.205 | -0.043 | 0.662 | -0.007 | 0.944 |
| BRI | -0.119 | 0.226 | -0.199 | **0.042** | 0.056 | 0.105 |
| BAI | -0.077 | 0.436 | -0.147 | 0.136 | -0.107 | 0.278 |

**Abbreviations:** BMI: body mass index; WHtR: waist-to-height ratio; WHR: waist-to-hip ratio; ABSI: body shape index; BRI: body roundness index; BAI: body adiposity index; FSH: follicle-stimulating hormone; LH: luteinizing hormone; E2: estradiol; r: Pearson correlation coefficient; $p < 0.05$ is considered statistically significant.

**Table 5** Relationships between Anthropometric Measurements and the Number of Pregnancies, Births, and Miscarriages in Fertile Women

| Anthropometric Measurements Fertile Women | Number of pregnancies | | Number of Births | | Number of Miscarriage | |
|---|---|---|---|---|---|---|
| | rs | p | rS | p | rS | p |
| **Height (m)** | -0.004 | 0.969 | -0.087 | 0.375 | 0.109 | 0.267 |
| **Weight (kg)** | 0.119 | 0.226 | 0.091 | 0.358 | 0.060 | 0.542 |
| **BMI (kg/m²)** | 0.118 | 0.231 | 0.163 | 0.096 | 0.065 | 0.511 |
| **Waist Circumference (cm)** | 0.223 | **0.022** | 0.176 | 0.073 | 0.163 | 0.097 |
| **WHtR (cm/cm)** | 0.214 | **0.028** | 0.199 | **0.042** | 0.118 | 0.230 |
| **Hip Circumference (cm)** | 0.096 | 0.328 | 0.030 | 0.764 | 0.084 | 0.393 |
| **WHR (cm/cm** | 0.206 | **0.035** | 0.150 | 0.127 | 0.072 | 0.466 |
| **ABSI** | 0.183 | 0.062 | 0.080 | 0.415 | 0.119 | 0.228 |
| **BRI** | 0.255 | **0.009** | 0.199 | **0.042** | 0.118 | 0.230 |
| **BAI** | 0.085 | 0.388 | 0.107 | 0.275 | 0.051 | 0.608 |

**Abbreviations:** BMI: Body mass index; WHtR: Waist-to-height ratio; WHR: Waist-to-hip ratio; ABSI: Body shape index; BRI: Body roundness index; BAI: Body adiposity index; rs: Spearman's rank correlation coefficient; p: Statistical significance value ($p < 0.05$).