

DXA-Measured Fat Distribution and Metabolic Risk in Women with PCOS

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ABSTRACT

Background: Polycystic Ovary Syndrome (PCOS) is a multifactorial endocrine disorder. It is commonly associated with insulin resistance (IR), central obesity, and poor metabolic outcomes. Measures such as body mass index (BMI) do not fully capture the metabolic risk associated with regional fat distribution.

Objective: To critically evaluate the current literature on the relationship between body fat distribution, insulin sensitivity, and metabolic parameters in women with PCOS, with an emphasis on studies employing Dual-Energy X-ray Absorptiometry (DXA) for body composition analysis.

Methods: A narrative review was conducted by searching PubMed, Scopus, and Web of Science for peer-reviewed articles published from January 2000 to June 2024. Studies were included if they met all of the following criteria: women of reproductive age diagnosed with PCOS according to standard criteria; used DXA to assess body composition or fat distribution; and reported associations with metabolic parameters, such as insulin resistance, lipid profiles, or glucose metabolism. Only observational studies (cross-sectional, case-control, or cohort) were considered.

Results: A total of seven DXA-based studies comprising approximately 282 women with PCOS and 215 controls were identified, with individual sample sizes ranging from 20 to 73 participants per group. Across these studies, visceral and android fat accumulation, particularly high trunk fat percentage and elevated android-to-gynoid fat ratio, were consistently associated with insulin resistance and dyslipidemia, independent of total body fat or BMI. These DXA-derived parameters demonstrated strong correlations with metabolic indices, including fasting insulin, HOMA-IR, and QUICKI, whereas subcutaneous fat showed comparatively weaker associations with adverse metabolic outcomes.

Conclusion: Regional fat distribution, rather than total adiposity, plays a pivotal role in modulating insulin sensitivity and metabolic risk in women with PCOS. DXA offers a superior, non-invasive modality for assessing these parameters and may enhance clinical risk stratification and guide targeted interventions. Future longitudinal and interventional studies are essential to establish causality and inform therapeutic strategies focused on regional fat modulation.

Keywords: Dual energy x-ray absorptiometry, Polycystic Ovary Syndrome, Body mass index, Android fat, Trunk fat.

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1. Background & Introduction

In women of reproductive age, polycystic ovary syndrome (PCOS) is one of the most frequently observed hormonal disorders. It is characterized by polycystic ovarian morphology (PCO), hyperandrogenism, and ovulatory dysfunction¹. Insulin resistance (IR), obesity, dyslipidemia, increased risk of type 2 diabetes (T2DM) and cardiovascular diseases (CVD) are all closely associated with PCOS, in addition to the challenges that are linked with reproduction². Although obesity is common in PCOS, body fat distribution is a more significant marker of metabolic

risk than total body fat alone³. Conventional anthropometric metrics, including body mass index (BMI), waist circumference (WC), and waist-to-hip ratio (WHR), are inadequate in precisely distinguishing visceral fat from subcutaneous fat⁴. Dual energy x-ray absorptiometry (DXA) offers a more accurate measurement of adipose mass, lean mass, and regional fat distribution⁵. This review aims to summarize the current literature exploring the relationship

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of DXA-measured body fat distribution with insulin sensitivity, glucose metabolism, and lipid profiles in women with PCOS.

1a. Body Fat Distribution in PCOS

The Android pattern of obesity, also known as central or abdominal adiposity, includes metabolically active visceral fat located around internal organs. This fat is strongly linked to insulin resistance and chronic inflammation through the secretion of proinflammatory cytokines (e.g., TNF- α , IL-6) and adipokines that impair insulin signalling, increasing risk of metabolic dysfunction and cardiovascular disease compared to the gynoid (peripheral) pattern.⁶ While body fat distribution is often estimated using waist circumference (WC), waist-to-hip ratio (WHR), and body mass index (BMI), these surrogate measures are indirect. Imaging techniques like DXA provide a more precise, compartment-specific evaluation of fat distribution enabling differentiation between visceral and subcutaneous depots^{7,8}

1b. Insulin Sensitivity and Metabolic Dysregulation in PCOS

DXA-derived measures of visceral fat are strong predictors of metabolic syndrome components in PCOS, including dyslipidemia, hypertension, and impaired glucose tolerance⁹. Increased visceral adiposity is associated with reduced insulin sensitivity, elevated triglycerides, decreased HDL cholesterol, and impaired glucose tolerance. Additionally, adipose tissue dysfunction contributes to the secretion of adipokines and pro-inflammatory cytokines that exacerbate IR⁶.

1c. Correlation between Fat Distribution and Metabolic Parameters

Research consistently demonstrates that women with PCOS who have higher central adiposity exhibit higher IR, reduced insulin sensitivity, elevated fasting insulin levels, increased triglycerides, reduced HDL cholesterol, and a greater prevalence of metabolic syndrome¹⁰. Conversely, women with predominantly peripheral fat distribution tend to have relatively better insulin sensitivity and a more favourable metabolic profile, even when total body fat is similar¹¹.

1d. DXA: A Precise Tool for Body Composition and Metabolic Assessment

DXA, originally developed for assessing bone mineral density, is now widely used for body composition analysis¹².

Using two low-dose X-ray beams, DXA distinguishes bone, lean tissue, and fat mass, providing accurate quantification of total and regional fat¹³.

DXA offers several advantages: it is highly accurate, reproducible, non-invasive, rapid (typically under 10 minutes), and exposes patients to minimal radiation, making it suitable for both clinical follow-up and research. Importantly, it can estimate visceral adipose tissue (VAT), a depot strongly linked to insulin resistance, dyslipidemia, and cardiovascular risk, and simultaneously evaluate bone mineral density, adding value in conditions such as PCOS where skeletal health may also be affected^{14,15}.

In women with PCOS, DXA has become an invaluable tool for assessing body fat distribution, as its precision correlates closely with insulin resistance, lipid abnormalities, and cardiometabolic risk. It allows monitoring of longitudinal changes, evaluation of therapeutic responses, and tailoring of individualized treatment strategies to reduce central obesity and improve metabolic outcomes¹².

Several studies have compared total, trunk, android, and gynoid fat distribution between PCOS and BMI-matched controls using DXA, with key findings summarized in Table 1.

1e. Constraints of DXA: Cost, Accessibility, and Portability

Despite its high precision and clinical utility, DXA scanning has certain limitations that restrict its widespread use in body fat assessment. The technique requires specialized equipment that is expensive to acquire and maintain, limiting its availability to well-resourced hospitals or research centers. Unlike simple anthropometric measures such as BMI, WC, or WHR, DXA is not portable and cannot be easily applied in field studies or community-based settings. In addition, access to trained personnel and dedicated facilities is essential, which may not be feasible in low-resource environments. These factors make DXA less practical for routine screening or large-scale epidemiological studies, despite its superiority in accuracy and compartment-specific fat analysis¹⁶.

2. Clinical Implications

Recognizing the impact of fat distribution on metabolic health in PCOS has significant clinical implications¹⁷.

(1) Targeted Interventions: Lifestyle interventions focusing on reducing visceral fat (e.g., aerobic exercise, dietary

modifications) may have superior benefits in improving insulin sensitivity compared to weight loss alone. (2) Personalized Management: Stratifying PCOS patients based on fat distribution may aid in personalized risk assessment and management. (3) Early Screening: Central obesity should prompt early metabolic screening, even in non-obese PCOS women.

3. Conclusion

This DXA-based review emphasizes the importance of fat distribution rather than total fat in shaping metabolic health in reproductive-age women with PCOS. Increased central adiposity, particularly visceral fat measured by DXA, is strongly linked to IR, elevated fasting insulin, adverse lipid profiles, and higher metabolic syndrome risk. Unlike BMI or WC, DXA provides a precise, region-specific assessment, distinguishing harmful android fat from protective gynoid fat. This enables better risk stratification and treatment monitoring. Incorporating DXA into clinical practice may guide targeted interventions to reduce central fat and improve metabolic outcomes.

4. Perspectives for Future Research

Randomized controlled trials (RCTs) are particularly

needed to evaluate how DXA-derived measures of visceral and regional fat distribution can guide targeted interventions, such as exercise regimens, dietary modifications, and pharmacological therapies aimed at reducing central adiposity and improving metabolic outcomes. Longitudinal studies incorporating DXA could also clarify the dynamics of fat redistribution over time and its association with IR, cardiovascular risk, and reproductive health in women with PCOS.

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Table 1: Summary Table: Key DXA-Based PCOS Studies

Author	Year	Country	Cases; Controls	Outcome regions	Results
Yucel et al	2006	Turkey	33; 21	Trunk fat (below the chin to the colli femuri) .Total Body fat.	Trunk fat increased. (P < 0.043) ¹⁸ .
Toscani et al	2007	Brazil	24; 13	Trunk fat (Total body fat mass minus the arms and legs fat mass).Total body fat %.	Trunk fat increased. (P= 0.038) ¹⁹ ,
Thomann et al	2008	Switzerland	20;19	Trunk fat (%). Total body fat (%).	Trunk fat increased. (P=0.002) ²⁰ .
Mierzwicka et al	2018	Poland	73;61	Android fat (%). Gyneoid fat (%). Total body fat (%).	Android fat (%) increased. (P<0.01) ²¹ .
Macruz et al	2017	Brazil	28;16	Trunk fat (%). Total body fat (%).	Trunk fat increased (%) (p=0.01) ²² .
Jedrzejuk et al	2016	Poland	62;43	Total body fat (%). Android fat (%). Gyneoid fat (%).	Total body fat increased (P=0.014). Android fat increased (P<0.013) ²³ .
Styaraddi et al	2019	India	42;42	Viseral fat (%). Total body fat (%).	Total body fat (%) increased. P=0.0001. Visceral fat increased. P=0.0001 ²⁴ .

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