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Sonographic Evaluation of Intra-Abdominal Fat Thickness and Its Relationship with Metabolic Syndrome and Chronic Kidney Disease

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Abstract **Original Research Article**

Background: Metabolic syndrome (MetS) and chronic kidney disease (CKD) are major public health concerns globally, with visceral adiposity playing a pivotal role. Sonographic measurement of intra-abdominal fat thickness (IAFT) provides a non-invasive method to assess central obesity, but its relationship with MetS and CKD is not well-studied in South Asian populations. ***Objectives:*** To investigate the association of sonographically measured IAFT with MetS and CKD among adults in Bangladesh. ***Methods:*** A cross-sectional analytical study was conducted at BIRDEM General Hospital and the National Institute of Kidney Diseases & Urology (NIKDU), Dhaka, from July 2021 to June 2023. A total of 148 adults undergoing abdominal ultrasonography were enrolled. IAFT was measured sonographically. MetS was defined using NCEP-ATP III criteria, and CKD was classified according to KDIGO 2012 guidelines. Data were analyzed using descriptive statistics, correlation analysis, and multivariate logistic regression. ***Results:*** The mean IAFT was 34.8 ± 7.5 mm, higher in males than females (36.2 ± 7.9 vs. 32.8 ± 6.8 mm; $p = 0.012$). The prevalence of MetS and CKD was 60.1% and 27.7%, respectively, with most CKD cases in early stages (Stage 1–2: 72.3%). IAFT was significantly higher in participants with MetS (38.6 ± 6.9 mm) and CKD (39.2 ± 7.1 mm) compared to those without (29.1 ± 5.4 mm and 32.8 ± 6.7 mm; $p < 0.001$). IAFT positively correlated with waist circumference ($r = 0.61$), fasting glucose ($r = 0.43$), triglycerides ($r = 0.37$), systolic blood pressure ($r = 0.31$), and serum creatinine ($r = 0.28$; all $p < 0.01$). Multivariate analysis showed IAFT independently predicted MetS (AOR: 2.8; 95% CI: 1.7–4.6; $p < 0.001$) and CKD (AOR: 2.3; 95% CI: 1.3–4.1; $p = 0.003$) after adjusting for age, sex, and BMI. ***Conclusion:*** Sonographic IAFT is strongly associated with both MetS and CKD, independent of age, sex, and BMI. IAFT may serve as a simple, easily available, cost effective, non-invasive, radiation free marker to identify individuals at risk for metabolic and renal complications, particularly in resource-limited settings.

Keywords: Intra-abdominal fat thickness, metabolic syndrome, chronic kidney disease, visceral adiposity, sonography, Bangladesh.

INTRODUCTION

Metabolic syndrome (MetS), characterized by central obesity, insulin resistance, dyslipidemia, and hypertension, has emerged as a major global health concern due to its strong association with cardiovascular and renal complications. Increasing evidence suggests that MetS substantially elevates the risk of chronic kidney disease (CKD), independent of traditional risk factors [1,2]. Large-scale cohort studies, including a 10-year prospective study from Korea, have demonstrated that individuals with MetS are at significantly higher risk of developing CKD compared to those without the syndrome [3]. Furthermore, visceral adiposity, a core component of MetS, has been shown to play a critical role in renal dysfunction through mechanisms involving inflammation, oxidative stress, and hemodynamic alterations [4].

The global burden of obesity and metabolic syndrome has contributed significantly to the rising prevalence of CKD, with epidemiological evidence indicating that the coexistence of these conditions accelerates renal damage [5]. Studies have shown that both the individual and combined components of metabolic syndrome, particularly hypertension, diabetes,

and dyslipidemia, exert synergistic effects on kidney function decline [6,7]. Visceral adiposity has emerged as a particularly important factor, with recent evidence suggesting that adipose tissue distribution, rather than overall obesity, is more strongly associated with renal and cardiometabolic outcomes [8]. These findings highlight the importance of evaluating central obesity and visceral fat measures in understanding the complex interplay between metabolic syndrome and CKD.

Despite growing evidence linking obesity, metabolic syndrome, and visceral adiposity with renal dysfunction, most existing studies have focused on specific populations such as peritoneal dialysis patients or individuals with type 2 diabetes and polycystic ovary syndrome, limiting the generalizability of findings to broader populations [9,10,11]. Furthermore, while recent reviews have highlighted the clinical implications and prognostic significance of adiposity in the progression of chronic kidney disease [12], little is known about the direct relationship between sonographically measured intra-abdominal fat thickness, waist circumference, and early markers of CKD in community-based populations. This research gap is particularly relevant in low- and middle-income countries, where the dual burden of obesity and non-communicable diseases is rapidly rising, yet imaging-based adiposity assessments remain underutilized in routine care. Therefore, this study aims to evaluate the association of intra-abdominal fat thickness and waist circumference with chronic kidney disease, building upon prior evidence and addressing an unmet need for population-level data in this field.

METHODOLOGY

Study Design and Setting

This cross-sectional analytical study was conducted in the Department of Radiology and Imaging, National Institute of Kidney Diseases & Urology (NIKDU) and Bangladesh Institute of Research and Rehabilitation in Diabetes, Endocrine and Metabolic Disorders (BIRDEM), Dhaka, Bangladesh, during a period of two years, from July 2021 to June 2023.

Study Population

Patients aged 18 years and above, referred to the Department of Radiology for abdominal ultrasonography during the study period, were considered for inclusion.

Inclusion Criteria

- Adults (≥18 years) who provided informed consent.
- Patients undergoing sonographic evaluation for abdominal assessment.
- Availability of relevant biochemical and clinical data for the diagnosis of metabolic syndrome and chronic kidney disease (CKD).

Exclusion Criteria

- Pregnant women.
- Patients with ascites, intra-abdominal mass, or prior abdominal surgery that could alter fat distribution.
- Patients with incomplete clinical, laboratory, or imaging data.

Sample Size and Sampling Technique

A total of 148 patients fulfilling the inclusion criteria were consecutively enrolled using purposive sampling.

Data Collection Procedures

After obtaining informed consent, detailed sociodemographic and clinical information was collected using a structured data collection sheet. Relevant laboratory values and clinical records were reviewed for metabolic and renal parameters.

Sonographic Assessment

All patients underwent ultrasonographic examination using a high-resolution real-time ultrasound machine with a 3.5–5 MHz convex probe. Intra-abdominal fat thickness (IAFT) was measured in the supine position during quiet respiration. The measurement was taken as the distance peritoneum and anterior margin of lumbar vertebra at the level of the umbilicus, following standard protocols. Each measurement was repeated thrice, and the mean value was recorded to minimize inter-observer variability.

Clinical and Biochemical Assessment

- **Metabolic Syndrome**: Defined according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) criteria, requiring the presence of at least three of the following:
  1. Waist circumference: ≥102 cm in men, ≥88 cm in women
  2. Triglycerides: ≥150 mg/dl (1.7 mmol/L) or drug treatment for elevated triglycerides
  3. HDL cholesterol: <40 mg/dl in men, <50 mg/dl in women, or treatment for low HDL
  4. Blood pressure: ≥130/85 mmHg or antihypertensive medication
  5. Fasting blood glucose: ≥100 mg/dl or treatment for diabetes mellitus

- **Chronic Kidney Disease (CKD)**: Defined according to KDIGO 2012 guidelines, based on estimated glomerular filtration rate (eGFR) calculated using the CKD-EPI equation and/or presence of albuminuria (urine albumin-to-creatinine ratio ≥30 mg/g) persisting for ≥3 months.

Data Analysis

Data were coded, entered, and analyzed using Statistical Package for the Social Sciences (SPSS) version 26. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages.

- **Comparisons** between groups (with vs. without metabolic syndrome or CKD) were performed using Student's t-test or Mann–Whitney U test for continuous variables, and chi-square test or Fisher's exact test for categorical variables.
- **Correlation** between intra-abdominal fat thickness and biochemical parameters was assessed using Pearson or Spearman correlation coefficients as appropriate.
- **Logistic regression analysis** was performed to evaluate the independent association of intra-abdominal fat thickness with metabolic syndrome and CKD, adjusting for potential confounders (age, sex, BMI, etc.). A p-value <0.05 was considered statistically significant.

Ethical Considerations

Ethical approval was obtained from the Institutional Review Board (IRB) of NIKDU and BIRDEM General Hospital, Dhaka, Bangladesh. Written informed consent was obtained from all participants prior to enrollment. Patient confidentiality was strictly maintained throughout the study.

RESULTS

Baseline Characteristics of Study Participants

A total of 148 participants were included in the analysis. Table 1 shows the socio-demographic and clinical profile of the study participants (N = 148). The majority of participants were in the 40–59year age group (50.0%), followed by those aged ≥60 years (28.4%), indicating a predominance of middle-aged and older adults. Males comprised 58.1%, slightly higher than females (41.9%). Regarding nutritional status, 45.9% were overweight and 25.7% obese, while only 28.4% had normal BMI, highlighting a high prevalence of excess body weight. Among the clinical conditions, hypertension (62.2%), diabetes mellitus (71.6%), and dyslipidemia (59.5%) were common, reflecting a high burden of metabolic risk factors in the study population.

Table 1: Socio-demographic and Clinical Characteristics of Participants (N = 148)

Variable	Category	Frequency (n)	Percent (%)
Age group (years)	<40	32	21.6
	40–59	74	50.0
	≥60	42	28.4
Sex	Male	86	58.1
	Female	62	41.9
BMI category	Normal (<25)	42	28.4
	Overweight (25–29.9)	68	45.9
	Obese (≥30)	38	25.7
Hypertension	Present	92	62.2
Diabetes mellitus	Present	106	71.6
Dyslipidemia	Present	88	59.5

Sonographic Measurement of Intra-Abdominal Fat Thickness

The mean intra-abdominal fat thickness (IAFT) was 34.8 ± 7.5 mm (range: 20–58 mm). Male participants had significantly higher IAFT compared to females (36.2 ± 7.9 mm vs. 32.8 ± 6.8 mm; p = 0.012). (Table 2)

Table 2: Intra-Abdominal Fat Thickness (IAFT) by Sex (N = 148)

Variable	Mean IAFT (mm) ± SD	Range (mm)	p-value
Male (n = 86)	36.2 ± 7.9	22–58	0.012*
Female (n = 62)	32.8 ± 6.8	20–50	
Overall (N = 148)	34.8 ± 7.5	20–58	

*Statistically significant (p < 0.05)

Prevalence of Metabolic Syndrome and Chronic Kidney Disease

Metabolic syndrome was identified in 89 participants (60.1%) according to NCEP-ATP III criteria. (Figure Ⅰ) Figure Ⅰ Ⅰ shows the prevalence and severity of chronic kidney disease (CKD) among the study participants. the majority of participants (72.3%) had early renal disease (Stage 1 and 2), indicating a high prevalence of mild kidney impairment. Stage 3 CKD was observed in 19.6% of participants, while Stage 4 CKD and Stage 5 CKD were found in 6.1% and 2.0%, respectively. Only 2.0% of participants had normal kidney function.

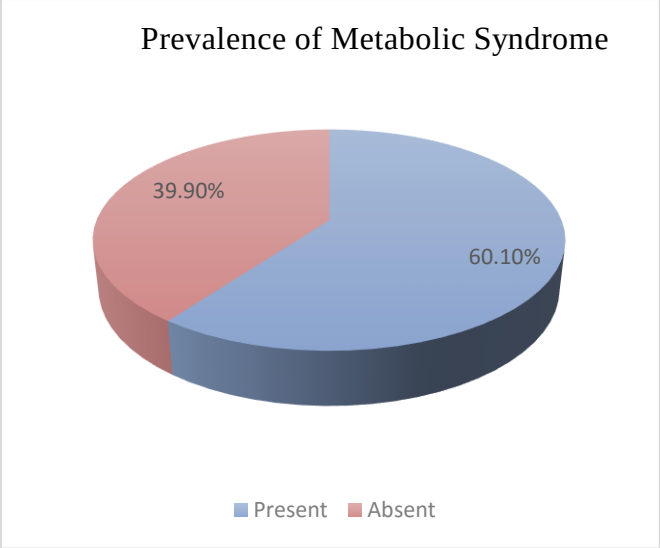

Figure Ⅰ: Prevalence of Metabolic Syndrome among Participants (N = 148)

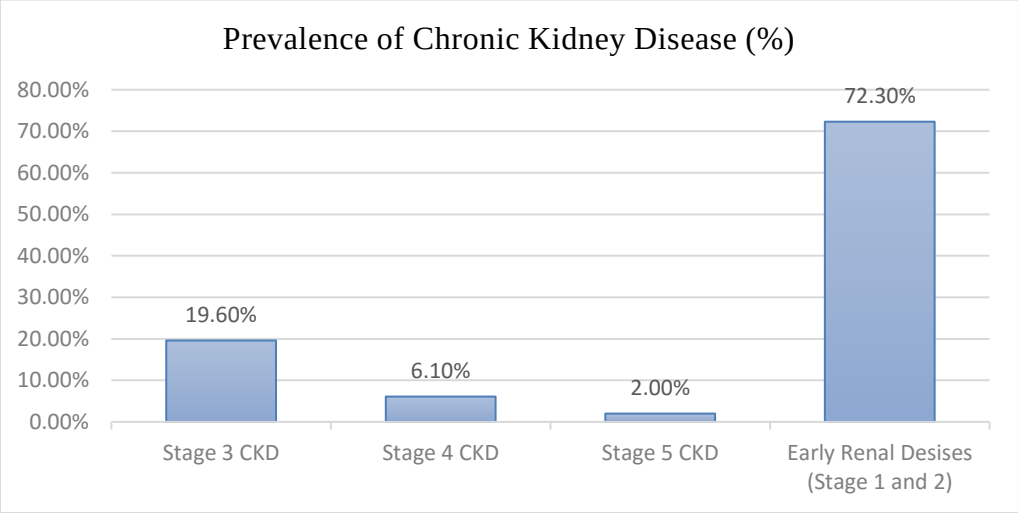

Figure ⅠⅠ: Prevalence of Chronic Kidney Disease

Components of Metabolic Syndrome

Table 3 presents the distribution of individual components of metabolic syndrome among the participants. Impaired fasting glucose or diabetes mellitus was the most prevalent component, affecting 71.6% of participants, followed by hypertension (62.2%) and central obesity (61.5%), indicating a high burden of cardiometabolic risk factors. Hypertriglyceridemia was present in 50.0%, while low HDL cholesterol was observed in 42.6% of participants.

Table 3: Components of Metabolic Syndrome Among Participants (N = 148)

Component	Present n (%)
Central obesity (Measured by USG)	91 (61.5)
Hypertriglyceridemia	74 (50.0)
Low HDL cholesterol	63 (42.6)
Hypertension	92 (62.2)
Impaired fasting glucose/DM	106 (71.6)

Association Between Intra-Abdominal Fat Thickness, Metabolic Syndrome, and CKD

Table 4 demonstrates the association between intra-abdominal fat thickness (IAFT) and the presence of metabolic syndrome and chronic kidney disease (CKD). Participants with metabolic syndrome had significantly higher IAFT (38.6 ± 6.9 mm) compared to those without metabolic syndrome (29.1 ± 5.4 mm; $p < 0.001$). Similarly, participants with CKD exhibited greater IAFT (39.2 ± 7.1 mm) than those without CKD (32.8 ± 6.7 mm; $p < 0.001$).

Table 4: Association of IAFT with metabolic syndrome and CKD (N = 148)

Condition	IAFT (mm, mean ± SD)	p-value
Metabolic Syndrome	38.6 ± 6.9	<0.001
No Metabolic Syndrome	29.1 ± 5.4	
CKD Present	39.2 ± 7.1	<0.001
CKD Absent	32.8 ± 6.7	

Correlation Analysis

Table 5 shows the correlation between intra-abdominal fat thickness (IAFT) and selected metabolic and renal parameters. Sonographic IAFT exhibited a strong positive correlation with CKD ($r = 0.61$, $p < 0.001$). Moderate positive correlations were observed with fasting blood glucose ($r = 0.43$, $p < 0.001$) and triglycerides ($r = 0.37$, $p < 0.001$), reflecting the link between increased IAFT and metabolic disturbances. IAFT was also positively correlated with systolic blood pressure ($r = 0.31$, $p = 0.002$) and serum creatinine ($r = 0.28$, $p = 0.004$).

Table 5: Correlation of Intra-Abdominal Fat Thickness (IAFT) Metabolic and renal parameter (N = 148)

Parameter	Correlation Coefficient (r)	p-value
IAFT measured by USG	0.61	<0.001
Fasting blood glucose	0.43	<0.001
Triglycerides	0.37	<0.001
Systolic blood pressure	0.31	0.002
Serum creatinine	0.28	0.004

Multivariate Analysis

The multivariate logistic regression analysis revealed that increased intra-abdominal fat thickness (IAFT) is an independent predictor of both metabolic syndrome and chronic kidney disease (CKD), even after adjusting for potential confounders such as age, sex, and BMI. Specifically, participants with higher IAFT had 2.8 times greater odds of having metabolic syndrome and 2.3 times greater odds of having CKD compared to those with lower IAFT.

Table 6: Multivariate Logistic Regression Analysis Showing Independent Association of IAFT with Metabolic Syndrome and CKD (N = 148)

Outcome	Adjusted Odds Ratio (AOR)	95% Confidence Interval (CI)	p-value
Metabolic Syndrome	2.8	1.7–4.6	<0.001
Chronic Kidney Disease	2.3	1.3–4.1	0.003

DISCUSSION

In this cohort of 148 participants at a tertiary care center in Dhaka, we observed a notably high prevalence of metabolic syndrome (60.1%), with concomitant high rates of obesity, hypertension, dyslipidemia, and impaired fasting glucose. Our sonographic measurement of intra-abdominal fat thickness (IAFT) correlated strongly with metabolic risk markers and was independently associated with both metabolic syndrome and chronic kidney disease (CKD). These findings provide support for the role of visceral adiposity in metabolic-renal interplay and the potential utility of ultrasonographic IAFT as a clinical marker.

Prevalence of Metabolic Syndrome

The 60.1% prevalence of metabolic syndrome in our study is higher than figures reported in many community-based surveys in Bangladesh. In a systematic review and meta-analysis of Bangladeshi populations, the pooled prevalence of metabolic syndrome was estimated around 30–40%, depending on the diagnostic criteria used [13]. Our higher prevalence likely reflects the hospital-based, high-risk nature of our sample (with high rates of hypertension and diabetes).

Associations of Visceral Fat with Metabolic Risk

Our mean IAFT of 34.8 ± 7.5 mm and its higher value in men compared to women is consonant with prior imaging and sonographic studies showing sexual dimorphism in visceral fat accumulation. The strong correlation ($r = 0.61$) between IAFT and waist circumference reinforces that sonographic IAFT is a valid surrogate for central adiposity. Similar relationships — between visceral fat measures and metabolic traits such as hyperglycemia, hypertriglyceridemia, and hypertension — have been documented in other populations [14,15,16].

For example, the CARDIAL-MS cohort recently reported that ultrasound-derived abdominal fat layers correlated with multiple metabolic syndrome features, supporting the idea that ultrasonography is a feasible, low-cost approach to assess visceral fat deposition in clinical settings [17]. Also, in obesity research more broadly, visceral (vs subcutaneous) adipose tissue is increasingly regarded as the more

metabolically harmful depot, with evidence that visceral adipocytes contribute more to insulin resistance, proinflammatory cytokine secretion, and lipotoxicity [18].

Visceral Fat and Chronic Kidney Disease

The prevalence of CKD in our cohort (27.7%) is substantial, and the finding of greater IAFT among participants with CKD (39.2 ± 7.1 mm vs 32.8 ± 6.7 mm) aligns with growing literature that links visceral adiposity to renal injury.

Recent narrative reviews suggest that visceral fat (and ectopic adipose depots) may exert deleterious renal effects through multiple mechanisms such as increased intra-abdominal pressure, renal compression, activation of the renin–angiotensin system, and low-grade inflammation inducing glomerular hyperfiltration and sclerosis [19,20]. In diabetic populations, perirenal fat thickness — a visceral fat depot adjacent to the kidney — has been singled out as significantly associated with CKD risk [21]. In a Chinese cross-sectional study using metabolic scores for visceral fat (METS-VF), higher visceral adiposity indices were independently associated with CKD after multivariable adjustment [22]. Visceral and abdominal obesity have been consistently implicated in the pathogenesis of metabolic syndrome and its complications, including renal dysfunction. The interplay between central adiposity, insulin resistance, dyslipidemia, and systemic inflammation contributes to early renal impairment, independent of generalized obesity [23].

Thus, our finding that IAFT retained an independent association with CKD (adjusted OR 2.3, 95% CI 1.3–4.1) after controlling for age, sex, and BMI strengthens the argument that visceral adiposity per se, rather than generalized obesity alone, may contribute to renal dysfunction.

Limitation of the Study:

This study used modest sample sizes and a single focal point, making it likely that the conclusions do not fully reflect the broader circumstances.

CONCLUSION

This study demonstrated that intra-abdominal fat thickness, measured sonographically, is independently associated with both metabolic syndrome and chronic kidney disease in a Bangladeshi hospital-based cohort. The strong correlations between IAFT and metabolic as well as renal parameters highlight the pathogenic role of visceral adiposity beyond generalized obesity. Given the rising prevalence of obesity-related disorders in South Asia, incorporating ultrasonographic IAFT assessment into routine clinical evaluation may provide a cost-effective tool for early risk stratification. Future longitudinal studies with larger, community-based samples are warranted to confirm causality and explore the utility of IAFT in predicting long-term metabolic and renal outcomes.

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