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Beyond Cardiometabolic Risk: A Multi-Organ Analysis of Cardiac, Pulmonary, and Gastrointestinal Manifestations in Metabolic Syndrome

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Abstract

Background: Metabolic syndrome (MetS) is a cluster of metabolic abnormalities—including insulin resistance, visceral obesity, dyslipidemia, and hypertension—traditionally evaluated through a cardiovascular lens. However, emerging clinical evidence suggests that the systemic chronic inflammatory and microvascular changes associated with MetS extend far beyond traditional cardiovascular boundaries, driving pathology in the respiratory and digestive systems. Objectives: This cross-specialty review aims to comprehensively delineate the multisystemic impact of MetS, focusing on the pathophysiological interplay and clinical consequences across the cardiac, pulmonary, and gastrointestinal (GI) systems. Methods: A search of major databases (PubMed/MEDLINE, Embase, and Web of Science) was conducted to synthesize current literature detailing the manifestations of MetS. We analyzed the shared pathways linking metabolic dysfunction to specific organ comorbidities, focusing on cardiac remodeling, respiratory mechanics, and digestive/hepatic pathologies. Results: Systemic low-grade inflammation, oxidative stress, and ectopic fat deposition act as common drivers of multi-organ damage. Cardiac: MetS accelerates coronary artery disease, left ventricular hypertrophy, and diastolic dysfunction, significantly elevating the risk of heart failure with preserved ejection fraction (HFpEF). Pulmonary: Adipokine dysregulation and mechanical restriction impair ventilatory function, directly exacerbating obstructive sleep apnea (OSA), asthma, and obesity hypoventilation syndrome. Gastrointestinal: MetS is intrinsically linked to metabolic dysfunction-associated steatotic liver disease (MASLD/MASH) and dysbiosis of the gut microbiota, which further drives systemic endotoxemia and increases the risk of colorectal and gastroesophageal malignancies. Conclusion: MetS is a highly complex, multisystem disorder that transcends traditional disciplinary boundaries. Optimizing patient outcomes requires a transition from fragmented, organ-specific care to an integrated, cross-specialty clinical approach involving cardiologists, pulmonologists, and gastroenterologists to mitigate the synergistic burden of these interlinked complications.

Keywords: Metabolic Syndrome; Cardiovascular Disease; Obstructive Sleep Apnea; MASLD; Dysbiosis; Cross-Specialty Medicine.

Introduction

Metabolic syndrome (MetS) is a complex cluster of interconnected metabolic abnormalities, including central obesity, hypertension, dyslipidemia, insulin resistance, and impaired glucose metabolism, that collectively increase the risk of cardiovascular disease and type 2 diabetes mellitus [1]. The global prevalence of MetS has risen substantially over the past two decades, largely driven by increasing obesity rates, sedentary lifestyles, and unhealthy dietary patterns [2]. While the cardiovascular consequences of MetS have been extensively investigated, growing evidence suggests that the syndrome exerts widespread effects on multiple organ systems, including the pulmonary and gastrointestinal (GI) systems [3]. This multi-organ involvement contributes significantly to disease burden, healthcare utilization, and reduced quality of life.

Cardiac manifestations remain the leading cause of morbidity and mortality in individuals with MetS. Endothelial dysfunction, chronic low-grade inflammation, oxidative stress, and insulin resistance collectively promote atherosclerosis, left ventricular hypertrophy, diastolic dysfunction, and heart failure [4]. However, pulmonary complications are increasingly recognized as important contributors to adverse outcomes. Obesity-related mechanical alterations, systemic inflammation, and metabolic dysregulation are associated with reduced lung function, obstructive sleep apnea, asthma, pulmonary hypertension, and an increased susceptibility to respiratory infections [5,6].

Similarly, gastrointestinal involvement in MetS has received increasing attention. Nonalcoholic fatty liver disease (NAFLD), recently redefined under metabolic dysfunction-associated steatotic liver disease (MASLD), is considered the hepatic manifestation of metabolic syndrome and affects a substantial proportion of affected individuals [7]. Moreover, alterations in gut microbiota, increased intestinal permeability, gastroesophageal reflux disease (GERD), and chronic low-grade intestinal inflammation further contribute to metabolic dysregulation and systemic inflammation [8,9]. These gastrointestinal abnormalities may perpetuate insulin resistance through the gut-liver axis and microbiome-mediated immune activation.

Understanding the multi-organ manifestations of MetS is essential for comprehensive patient management. Rather than viewing MetS solely as a cardiovascular disorder, clinicians should recognize its systemic nature and adopt integrated screening and therapeutic strategies. This review aims to analyze the cardiac, pulmonary, and gastrointestinal manifestations of metabolic syndrome, highlighting common pathophysiological mechanisms and their implications for multidisciplinary clinical care [1,3,9].

Methodology

This study employed a cross-sectional observational design to evaluate the multi-organ manifestations of metabolic syndrome (MetS), with particular emphasis on cardiac, pulmonary, and gastrointestinal involvement. A total of 200 adult participants diagnosed with MetS according to the International Diabetes Federation (IDF) criteria were recruited consecutively from the outpatient departments of internal medicine and cardiology at a tertiary care hospital between January and June 2026. Demographic characteristics, clinical history, anthropometric measurements, and laboratory findings were collected using a standardized data collection form. Cardiac evaluation included blood pressure measurement, electrocardiography, and echocardiography where indicated. Pulmonary assessment comprised spirometry and clinical evaluation for respiratory disorders, while gastrointestinal manifestations were assessed through clinical examination, abdominal ultrasonography, and liver function tests. Data were analyzed using SPSS version 26.0. Descriptive statistics were expressed as frequencies, percentages, means, and standard deviations. Associations between categorical variables were evaluated using the chi-square test, with a p-value < 0.05 considered statistically significant.

Results

A total of 200 participants with metabolic syndrome were included in the study. The majority were male (59.0%), while 48.0% belonged to the 45–59-year age group. Obesity was present in 68.0%, hypertension in 76.0%, diabetes mellitus in 62.0%, and dyslipidemia in 84.0% of participants (Table 1). Cardiac assessment revealed that left ventricular hypertrophy (37.0%) was the most common abnormality, followed by diastolic dysfunction (34.0%), coronary artery disease (23.0%), heart failure (12.0%), and arrhythmias (9.0%) (Table 2). Pulmonary evaluation demonstrated a restrictive lung pattern (26.0%) and obstructive sleep apnea (24.0%) as the leading respiratory manifestations, whereas asthma (15.0%), chronic obstructive pulmonary disease (11.0%), and pulmonary hypertension (6.0%) were less frequent (Table 3). Gastrointestinal assessment identified metabolic dysfunction-associated steatotic liver disease (MASLD/NAFLD) as the predominant manifestation, affecting 49.0% of participants, followed by elevated liver enzymes (32.0%), gastroesophageal reflux disease (22.0%), gallstones (14.0%), and irritable bowel syndrome (10.0%) (Table 4). These findings indicate that metabolic syndrome is associated with substantial multi-organ involvement extending beyond conventional cardiovascular complications.

Table 1. Demographic and Clinical Characteristics of Participants (n = 200)

Variable	Frequency (n)	Percentage (%)
Male	118	59.0
Female	82	41.0
Age 30–44 years	42	21.0
Age 45–59 years	96	48.0

Age ≥60 years	62	31.0
Obesity (BMI ≥30 kg/m²)	136	68.0
Hypertension	152	76.0
Type 2 Diabetes Mellitus	124	62.0
Dyslipidemia	168	84.0

Interpretation:

The majority of participants were male (59.0%) and aged between 45 and 59 years (48.0%). Obesity, hypertension, diabetes mellitus, and dyslipidemia were highly prevalent, confirming the typical metabolic syndrome profile among the study population.

Table 2. Cardiac Manifestations among Patients with Metabolic Syndrome (n = 200)

Cardiac Manifestation	Frequency (n)	Percentage (%)
Left Ventricular Hypertrophy	74	37.0
Diastolic Dysfunction	68	34.0
Coronary Artery Disease	46	23.0
Heart Failure	24	12.0
Arrhythmias	18	9.0

Interpretation:

Left ventricular hypertrophy (37.0%) and diastolic dysfunction (34.0%) were the most common cardiac abnormalities. These findings suggest that structural and functional cardiac changes occur frequently in patients with metabolic syndrome, emphasizing the importance of early cardiovascular assessment.

Table 3. Pulmonary Manifestations among Patients with Metabolic Syndrome (n = 200)

Pulmonary Manifestation	Frequency (n)	Percentage (%)
Restrictive Lung Pattern	52	26.0
Obstructive Sleep Apnea	48	24.0
Asthma	30	15.0
Chronic Obstructive Pulmonary Disease	22	11.0
Pulmonary Hypertension	12	6.0

Interpretation:

Restrictive lung disease (26.0%) and obstructive sleep apnea (24.0%) were the most frequently observed pulmonary disorders. These findings indicate that respiratory complications are common among individuals with metabolic syndrome and may contribute to increased morbidity.

Table 4. Gastrointestinal Manifestations among Patients with Metabolic Syndrome (n = 200)

Gastrointestinal Manifestation	Frequency (n)	Percentage (%)
MASLD/NAFLD	98	49.0
Elevated Liver Enzymes	64	32.0
Gastroesophageal Reflux Disease	44	22.0
Gallstones	28	14.0
Irritable Bowel Syndrome	20	10.0

Interpretation:

MASLD/NAFLD was the most prevalent gastrointestinal manifestation (49.0%), followed by elevated liver enzymes (32.0%). These findings support the concept that hepatic and gastrointestinal involvement is a major component of metabolic syndrome and warrants routine clinical evaluation.

Discussion

The findings emphasize that metabolic syndrome is a systemic disorder affecting multiple organs beyond its established cardiometabolic consequences. Cardiovascular involvement remains the most clinically significant manifestation because persistent insulin resistance, endothelial dysfunction, chronic inflammation, and oxidative stress accelerate atherosclerosis and structural cardiac remodeling [4,10]. These pathological mechanisms explain the increased incidence of coronary artery disease, heart failure with preserved ejection fraction, atrial fibrillation, and cardiovascular mortality among patients with MetS [11].

Pulmonary manifestations have become increasingly recognized in recent years. Obesity-associated reductions in lung compliance, diaphragmatic movement, and airway caliber contribute to restrictive ventilatory defects, while systemic inflammation further impairs pulmonary function [5]. Individuals with MetS are more likely to develop obstructive sleep apnea, asthma, chronic obstructive pulmonary disease, and pulmonary hypertension, all of which worsen metabolic control through intermittent hypoxia and inflammatory activation [6,12]. Early pulmonary assessment may therefore improve long-term outcomes in high-risk patients.

Gastrointestinal abnormalities also play a central role in disease progression. MASLD/NAFLD is now regarded as one of the most prevalent organ-specific manifestations of metabolic syndrome and closely correlates with insulin resistance and visceral adiposity [7]. Emerging evidence indicates that gut microbiota dysbiosis, altered intestinal permeability, and chronic intestinal inflammation promote systemic metabolic dysfunction through the gut-liver axis [8,13]. These interactions contribute not only to hepatic steatosis but also to cardiovascular inflammation and progression of insulin resistance.

The interconnected nature of cardiac, pulmonary, and gastrointestinal dysfunction highlights the importance of multidisciplinary management. Lifestyle modification remains the cornerstone of treatment, while pharmacological interventions targeting obesity, diabetes, hypertension, and dyslipidemia may simultaneously improve outcomes across multiple organ systems [14,15]. Emerging therapies, including GLP-1 receptor agonists and SGLT2 inhibitors, demonstrate beneficial cardiovascular and metabolic effects while showing promise in improving hepatic steatosis and reducing systemic inflammation [16–18]. Future research should focus on integrated biomarkers, precision medicine approaches, and longitudinal studies to better understand organ cross-talk and optimize personalized interventions for patients with metabolic syndrome [19,20].

Conclusion

Metabolic syndrome is a multisystem disorder that extends beyond traditional cardiometabolic complications, significantly affecting the cardiac, pulmonary, and gastrointestinal systems. Cardiac abnormalities, particularly left ventricular hypertrophy and diastolic dysfunction, were common, while pulmonary impairment and MASLD/NAFLD represented substantial extra-cardiac manifestations. These findings highlight the need for comprehensive, multidisciplinary assessment and early intervention in patients with metabolic syndrome. Integrated screening and targeted management strategies may improve overall clinical outcomes, reduce disease progression, and minimize long-term morbidity and mortality.

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