

Determinants of Metabolic Syndrome in Asian Adults: A Scoping Review

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ABSTRACT

This review shows that metabolic syndrome (MetS) develops from a combination of several factors that work together rather than from one single cause. The studies reviewed indicate that excess body weight, poor diet, lack of physical activity, and sedentary habits are the main contributors to MetS. People who follow balanced and traditional diets that include fruits, vegetables, and natural foods tend to have a lower risk. Meanwhile, modern eating habits and processed foods increase the likelihood of developing MetS.

In addition, higher levels of inflammation and poor socioeconomic conditions also make individuals more vulnerable. These findings suggest that MetS prevention should focus on promoting healthy lifestyle changes through better nutrition, regular exercise, and early risk detection. Future programs and research need to integrate these factors and adapt them to local cultures to reduce the growing burden of MetS in the community.

Keywords: *Metabolic Syndrome; Risk Factors; Dietary Patterns; Physical Activity.*

INTRODUCTION

Metabolic syndrome (MetS) is a cluster of interrelated risk factors that collectively contribute to the development of cardiovascular diseases and diabetes. The key components of MetS include elevated blood glucose (hyperglycemia), hypertension, hypertriglyceridemia, reduced high-density lipoprotein cholesterol (HDL-C), insulin resistance, and central (abdominal) obesity (Mohamed et al., 2023). Each of these factors independently increases the risk of diabetes, cardiovascular morbidity, and mortality. However, when these components coexist as a syndrome, their combined effect amplifies the overall risk, exceeding the sum of the individual contributions .

The etiology of MetS remains a subject of ongoing debate among researchers. Nevertheless, abdominal obesity and insulin resistance are widely recognized as the central features driving its development (Sultana et al., 2024). In addition, several lifestyle and biological factors—including genetic susceptibility, physical inactivity, smoking, unhealthy dietary habits, aging, hormonal imbalances, and chronic low-grade inflammation are thought to contribute to the onset of MetS. The relative impact of these factors may vary across different ethnic and population groups (Dhondge et al., 2024).

The pathophysiological basis of MetS is increasingly linked to a persistent proinflammatory state, often triggered by excessive caloric intake, overnutrition, and other chronic inflammatory conditions. This inflammatory milieu, characterized by elevated levels of cytokines and oxidative stress, can disrupt normal metabolic signaling, impair insulin

sensitivity, and initiate a cascade of metabolic abnormalities (Kheirandish et al., 2024). Consequently, insulin resistance is considered the unifying mechanism that interconnects the various components of the syndrome (Mohamed et al., 2023; Zeng et al., 2024). Globally, the prevalence of MetS has risen substantially, affecting an estimated 20–25% of the adult population, largely driven by the increasing prevalence of obesity and sedentary lifestyles (Subías-Perié et al., 2022; Wan et al., 2025).

Although metabolic syndrome holds significant clinical and public health relevance, research across Asia remains relatively scarce—especially concerning its prevalence and underlying determinants. The lack of robust epidemiological data limits a clear understanding of the syndrome’s true burden in the region. Accordingly, this study seeks to consolidate existing evidence to present a comprehensive synthesis of MetS prevalence and its associated risk factors among Asian adult populations.

METHODS

This scoping review was conducted following the methodological framework proposed by Xiao and Watson (2019). The review process involved several sequential steps by identifying the research problem, developing and validating the review protocol, conducting a comprehensive literature search, screening and selecting relevant studies, extracting and analyzing data, synthesizing findings, and reporting the results systematically. A structured search strategy was designed to identify peer-reviewed articles examining the determinants of metabolic syndrome among Asian adults. Searches were performed across major academic databases, including Scopus, PubMed, Google Scholar. The search utilized English keywords: (“determinant” OR “risk factors” OR “associated factors”) AND (“metabolic syndrome” OR “MetS”) AND (“adults” OR “adult population”) AND (“Asia” OR “Asian”). In addition, searches using Indonesian terms were also applied to capture locally indexed studies: (“determinan” OR “faktor risiko” OR “faktor yang berhubungan”) AND (“sindrom metabolik” OR “MetS”) AND (“dewasa”) AND (“Asia” OR “Asia Tenggara”).

The inclusion criteria comprised studies published between 2020 and 2024, available in full-text format, written in English, and employing cross-sectional, case-control, or cohort research designs. Studies focusing on specific subpopulations Asian adults or non-Asian regions were excluded. From an initial yield of articles identified across databases, duplicates were removed, and titles and abstracts were screened for relevance. After full-text review, studies met the eligibility criteria and were included in the final synthesis. Excluded papers consisted of preprints, non-peer-reviewed manuscripts, and articles without full-text access. The findings were synthesized narratively to highlight the key determinants of metabolic syndrome among adult populations in Asia.

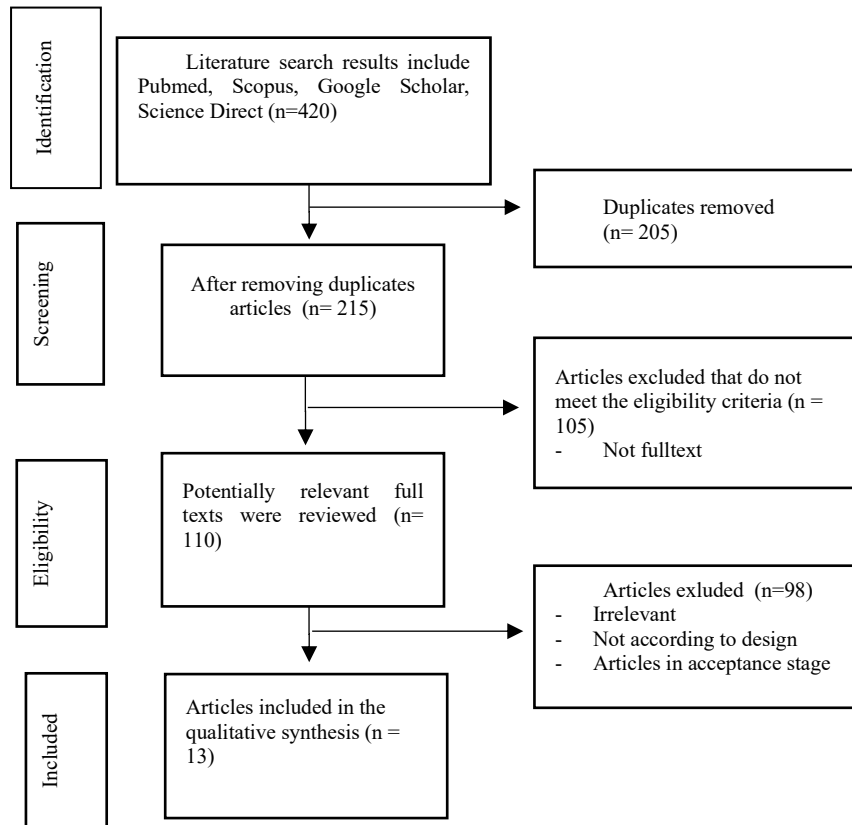


Figure 1. PRISMA Flow Diagram for Database Search of Studies

RESULTS

The data extracted from the selected studies provide a comprehensive overview of the characteristics, methodologies, and principal findings related to the determinants of metabolic syndrome (MetS) in adult populations. A total of twelve primary studies were included in this review, representing diverse geographic regions, sample sizes, and analytical approaches. The studies varied in design—most being cross-sectional—with a few employing longitudinal or cohort frameworks. Collectively, these studies examined a wide range of risk factors associated with MetS, including sociodemographic characteristics, lifestyle behaviors, dietary patterns, biochemical and inflammatory biomarkers, as well as anthropometric indicators. Each study contributed unique insights into how these variables interact to influence the prevalence and severity of MetS within different populations. Table 1 below summarizes the essential details extracted from each included article, encompassing the study’s country of origin, number of participants, study design, key results, and database source.

Table 1. Results of Data Extraction

Author and Year	Country	Participant	Study Design	Results	Database
(Wu et al., 2020)	China	2580	Cross-sectional	The age-standardized prevalence of metabolic syndrome was 21.1% and	PubMed

				<p>15.2% among all participants, respectively. When stratified by sex, the prevalence was 19.6% and 17.1% in men, and 22.7% and 13.0% in women, according to the respective diagnostic criteria. Notably, rural participants—particularly women—exhibited a significantly higher prevalence of MetS compared with their urban counterparts, while no significant difference was observed among men across residential settings. Multivariable analysis identified lower educational attainment and menopausal status as independent determinants of MetS.</p>	
(Ali et al., 2023)	Bangladesh	583	Cross-sectional	<p>This study revealed a high prevalence of metabolic syndrome (MetS) among university populations in Bangladesh—27.7% in students and 47.7% in staff. MetS was significantly more common in male than female students, while the opposite trend was observed among staff, though not statistically significant. The prevalence and its components increased with age, with low HDL-C being the most frequent abnormality. Logistic regression identified age, BMI, hypertension, and dyslipidemia as key determinants of MetS in both groups, with additional associations of low physical activity and smoking among students. These findings highlight the urgent need for</p>	PubMed

				targeted health promotion programs—particularly lifestyle interventions such as balanced diet and regular exercise—within academic institutions in Bangladesh.	
(Kou et al., 2024)	China	5918	Cross-sectional	Participants adhering to the traditional pattern had a significantly lower risk of MetS (Q4: OR = 0.58, 95% CI: 0.48–0.69; Q3: OR = 0.75, 95% CI: 0.63–0.89), whereas those following the modern pattern showed an increased risk (Q4: OR = 1.40, 95% CI: 1.17–1.68; Q3: OR = 1.27, 95% CI: 1.06–1.52). Mediation analysis revealed that insulin resistance partially explained the association between dietary patterns and MetS. This study suggest that adherence to a traditional dietary pattern may protect against MetS, while a modern dietary pattern may elevate its risk through mechanisms involving insulin resistance.	PubMed
(Permatasari et al., 2023)	Indonesia	14.302	Cross-sectional	This study found that both individuals with and without central obesity had a significantly higher risk of metabolic syndrome ($p < 0.05$) associated with the frequent consumption of various unhealthy foods, including sweet, savory, fatty, fried, grilled, and processed foods, as well as soft drinks, energy drinks, and instant products. Among those without central obesity, frequent use of seasonings was significantly linked to a higher risk of metabolic syndrome (OR =	Google scholar

				1.519, 95% CI: 1.241–1.859), while among those with central obesity, the significant risk factor was frequent consumption of sugary drinks (OR = 1.315, 95% CI: 1.132–1.529). Additionally, insufficient intake of fruits and vegetables and low physical activity independently increased the risk of metabolic syndrome in both groups ($p < 0.05$).	
(You et al., 2023)	China	Elderly population (4360)	Cross-sectional	Among 4,360 participants, 2,378 (54.5%) were diagnosed with metabolic syndrome (MetS). The mean uric acid (UA) level was 331 ± 86 $\mu\text{mol/L}$, while the median (IQR) levels of homocysteine (HCY) and high-sensitivity C-reactive protein (HsCRP) were 15 (13–18) $\mu\text{mol/L}$ and 1.0 (0.5–2.1) mg/L , respectively. Participants with elevated non-traditional cardiovascular risk factors (CVRFs) had a significantly higher risk of MetS ($P < 0.001$), consistent across most subgroups (P -interaction > 0.05). Body mass index (BMI) mediated approximately 44% of the association between hyperuricemia (HUA) and MetS, 37% for hyperhomocysteinemia (HHCY), and 31% for high HsCRP (HHsCRP). Moreover, the coexistence of abnormal non-traditional CVRFs and overweight/obesity markedly amplified MetS risk, with	Scopus

				adjusted ORs ranging from 3.9 to 7.7 depending on the combination (e.g., HUA + obesity: OR = 6.15; HHsCRP + obesity: OR = 7.72).	
(Zeng et al., 2024)	China	Middle–older adults (6220)	Cohort	A higher metabolic syndrome (MetS) score was significantly linked to an elevated risk of frailty (HR per 1 SD increase = 1.205; 95% CI: 1.14–1.27) and a faster frailty index (FI) progression (β = 0.113 per year; 95% CI: 0.075–0.15). Similarly, a 1 SD increase in the cumulative MetS score raised frailty risk by 22.2% (OR = 1.222; 95% CI: 1.133–1.319) and accelerated FI increase by 0.098 per year (95% CI: 0.058–0.138). Restricted cubic spline analysis revealed a clear dose–response relationship between both MetS and cumulative MetS scores with frailty risk. Stratified analyses confirmed consistent results across subgroups, with interactions suggesting that MetS more strongly accelerates FI progression in men and individuals younger than 60 years.	Scopus
(Zhao et al., 2023)	China	68383 participants aged 18-80 years	Cross-sectional	A total of 26,113 men and 24,582 women exhibited abnormal metabolic syndrome (MetS) components, with significant differences observed across most epidemiological characteristics among the six MSSS groups. The three most prevalent abnormalities were elevated systolic blood pressure (SBP) (9.41%, n =	Pubmed

				6,568), increased waist circumference (WC) (8.13%, n = 6,120), and the coexistence of high SBP and WC (6.33%, n = 4,622). Individuals with low HDL-C levels were more likely to exhibit all five MetS components. Restricted cubic spline analysis revealed that MetS prevalence in men peaked when MSSS \geq 3, while in women, the prevalence increased most sharply between the ages of 40 and 60.	
(Anggraini K, 2024)	Indonesia	9,220 men aged 15 to 97 years	Cross-sectional	The development of metabolic syndrome (MetS) is influenced by several behavioral and physiological factors, including body mass index, smoking exposure, physical activity levels, alcohol intake, dietary habits, and inadequate fruit and vegetable consumption. Using Chi-square tests and multiple logistic regression analyses, the study identified that the prevalence of MetS was highest under the JIS criteria (19.5%), compared to the NCEP/ATP III (10.7%) and IDF (11.0%) definitions. The occurrence of MetS and its individual components showed a clear upward trend with advancing age. Significant predictors of MetS included age between 30 and 79 years, excess body weight (from overweight to Grade 3 obesity), heavy smoking exposure (smoking index 200–400 and >400), and insufficient physical	Google Scholar

				activity. The study underscores the urgent need for tailored prevention strategies that address lifestyle factors to curb the increasing burden of MetS, particularly among Indonesian men.	
(Kheirandish et al., 2024)	Iran	4063 people aged 35 to 70	Cross-sectional	Three primary dietary patterns were identified: healthy, western, and traditional. After adjusting for potential confounders, individuals in the highest quintile of adherence to the healthy dietary pattern had a 46% lower likelihood of developing metabolic syndrome compared to those in the lowest quintile. Fully adjusted models for individual MetS components revealed that greater adherence to the healthy pattern was significantly associated with reduced odds of elevated blood glucose, increased waist circumference, and high blood pressure. In contrast, the western and traditional dietary patterns showed no significant associations with either the overall risk of metabolic syndrome or its individual components after full adjustment.	Scopus
(Rahmawati et al., 2024)	Indonesia	1,376 Indonesian adult participants,	Cohort (6 years)	Overweight and obesity were strong predictors of metabolic syndrome (MetS), with overweight individuals having a 2.4-fold higher risk and obese individuals a 4.4-fold higher risk compared to those with normal body mass index (BMI) (95% CI: 1.176–	PubMed

				3.320 and 3.345–5.740, respectively). Participants engaging in less intentional physical exercise exhibited a 1.5-fold greater risk of MetS (95% CI: 1.034–2.109) than those with higher exercise levels. Dietary composition also played a key role—participants in the second quartile of fat intake had a 30% lower risk of MetS (95% CI: 0.505–0.972) relative to those in the lowest quartile, while those in the second quartile of carbohydrate intake showed a 1.5-fold higher risk (95% CI: 1.063–2.241). These findings highlight the interplay between body weight, physical activity, and macronutrient balance in influencing MetS risk.	
(Yang et al., 2024)	China	10,520 participants aged 18-85 years	Cross-sectional	Among 3,324 participants (31.6%) diagnosed with metabolic syndrome (MetS), all eight anthropometric and metabolic indexes were significantly associated with higher MetS risk after adjustment ($p < 0.05$). The strongest predictors were the Lipid Accumulation Product (LAP, adjOR = 35.69) and Waist-to-Height Ratio (WHtR, adjOR = 29.27), followed by the Conicity Index, TyG Index, BMI, WWI, VAI, and ABSI. Restricted cubic spline analyses showed nonlinear associations for all indexes ($P_{\text{non-linear}} < .001$). WHtR was the best MetS predictor in men (AUC = 0.91; cutoff =	Scopus

				0.53), while LAP was strongest in women (AUC = 0.89; cutoff = 28.67), confirming their superior diagnostic value compared to other indices.	
(Sultana et al., 2024)	South Asia	Multi-country adults (27.616)	Cross-sectional	Among South Asian adults, 34% had a high metabolic comorbidity score, with prevalence rates of 25% in men and 41% in women. Individuals reporting physical inactivity (OR = 1.26; 95% CI: 1.17–1.36), prolonged sedentary behavior (OR = 1.24; 95% CI: 1.11–1.33), or alcohol consumption (OR = 1.40; 95% CI: 1.23–1.53) were more likely to exhibit higher metabolic comorbidity scores compared to those who were active, less sedentary, and abstained from alcohol. Interestingly, tobacco use showed a negative association with metabolic comorbidity (OR = 0.75; 95% CI: 0.71–0.81), suggesting a complex or potentially confounded relationship.	PubMed
(Wan et al., 2025)	Malaysia	1035	Cross-sectional	The study achieved a 71.4% response rate, including 1,035 participants. The overall prevalence of metabolic syndrome (MetS) was 35.9% (95% CI: 31.4–40.6), representing approximately 8.5 million Malaysian adults. Among the MetS components, abdominal obesity was most prevalent (52.8%), followed by low HDL-cholesterol (44.6%), elevated blood pressure (43.4%), elevated triglycerides (33.4%), and	Scopus

				<p>elevated fasting glucose (21.5%). Multivariate analysis identified advancing age, Indian ethnicity (aOR = 2.24; 95% CI: 1.19–4.22), elevated aspartate aminotransferase (aOR = 3.09; 95% CI: 1.50–6.35), and elevated gamma-glutamyl transferase (aOR = 3.30; 95% CI: 1.84–5.92) as independent predictors of MetS. These findings highlight a substantial burden of MetS in Malaysia, particularly among older adults and those with hepatic enzyme abnormalities, underscoring the need for targeted prevention strategies within high-risk populations.</p>	
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Table 1 summarizes the key characteristics and major findings of the twelve studies included in this scoping review, which collectively explore diverse determinants and outcomes related to metabolic syndrome (MetS) across adult populations in Asia and beyond. Overall, the studies varied in design, participant demographics, and analytical scope, yet converged on several consistent themes regarding risk distribution and underlying correlates of MetS. The earliest study by Wu et al. (2020) in China identified that the age-standardized prevalence of MetS ranged between 15% and 21% depending on the diagnostic criteria used. Notably, rural participants—particularly women—exhibited a significantly higher prevalence than their urban counterparts, suggesting that socioeconomic and lifestyle transitions may contribute to growing metabolic risks in less urbanized areas. Similarly, Ali et al. (2023) reported that overweight status, hypertension, dyslipidaemia, and low physical activity were the most important predictors of MetS among university staff and students, with prevalence varying markedly between the two groups.

Nutritional and dietary patterns also appeared as dominant determinants. In a longitudinal analysis, Kou et al. (2024) demonstrated that adherence to traditional Chinese dietary patterns was associated with a significantly lower risk of MetS, while adherence to modern, high-fat, high-sugar diets increased the likelihood of developing the syndrome. This dietary effect was further mediated by insulin resistance. Likewise, Permatasari et al. (2023) observed that frequent consumption of processed and sugary foods substantially elevated MetS risk among Indonesian adults, while inadequate fruit and vegetable intake and low physical activity were additional contributors. Several studies focused on biochemical and inflammatory correlates. You et al. (2023) reported that elevated levels of uric acid, homocysteine, and C-reactive protein were strongly associated with MetS and that body mass index (BMI) mediated more than 30% of these associations. These findings emphasize the

interplay between adiposity, oxidative stress, and low-grade inflammation in the pathogenesis of MetS. In another cohort, Zeng et al. (2024) linked higher cumulative MetS scores to an increased risk of frailty and faster functional decline, particularly among men and individuals under 60 years of age, thereby expanding the consequences of MetS beyond metabolic regulation to systemic aging processes.

The study by Zhao et al. (2023) highlighted that high systolic blood pressure (SBP) and large waist circumference (WC) were the most prevalent abnormal components, and their co-occurrence accounted for more than 6% of total cases. This aligns with the results from Anggraini et al. (2024), which confirmed that advancing age, obesity grades, smoking index, and low physical activity were independently associated with higher MetS prevalence among Indonesian men. Similarly, Rahmawati et al. (2024) found that overweight and obesity increased the risk of MetS by 2.4-fold and 4.4-fold, respectively, whereas higher fat intake within moderate ranges was protective, underscoring the complex role of dietary composition. The Kheirandish et al. (2024) investigation confirmed that a healthy dietary pattern reduced MetS risk by 46% compared to the lowest adherence quintile, mainly through improvements in waist circumference, blood pressure, and fasting glucose. Meanwhile, Sultana et al. (2024), in a large South Asian cohort, revealed that physical inactivity, alcohol use, and prolonged sedentary behavior significantly increased metabolic comorbidity, while an unexpected inverse association was observed for tobacco use—possibly reflecting residual confounding or reverse causation. Evidence from the JMIR (2024) study comparing eight anthropometric indices found that the lipid accumulation product (LAP) and waist-to-height ratio (WHtR) were the most accurate predictors of MetS, with gender-specific thresholds (WHtR = 0.53 for men, LAP = 28.7 for women). These results portray MetS as a multifactorial condition influenced by biological, lifestyle, and environmental variables. Obesity and diet emerge as the most consistent predictors, while inflammation, physical inactivity, and socioeconomic context amplify individual susceptibility. The convergence of findings across countries and study designs strengthens the evidence base for developing integrated, culturally adapted prevention programs targeting modifiable behavioral and metabolic risk factors.

Table 1 The Related Factors Affecting Metabolic Syndrome

Related Factors	Significant Risk Factors	Main Empirical Source
Sociodemographic, education, residence, menopausal status	Lower education and menopausal status identified as independent determinants of MetS; age-standardized prevalence reported (MS: 21.1% and 15.2% by criteria); rural women had higher prevalence than urban women (stat significance reported).	(Wu et al., 2020)
Age, BMI, hypertension, dyslipidemia, low physical activity, smoking	Age, BMI, hypertension and dyslipidemia were key determinants; low physical activity and smoking additionally associated in students; prevalence: students 27.7%, staff 47.7%.	(Ali et al., 2023)

Dietary patterns — traditional vs modern	Traditional dietary pattern associated with lower MetS risk (Q4 OR=0.58, 95% CI: 0.48–0.69; Q3 OR=0.75, 95% CI: 0.63–0.89); Modern pattern associated with higher risk (Q4 OR=1.40, 95% CI: 1.17–1.68; Q3 OR=1.27, 95% CI: 1.06–1.52); mediation by insulin resistance.	(Kou et al., 2024)
Unhealthy food consumption, seasonings, sugary drinks, fruits and vegetables, physical activity, central obesity	Frequent consumption of sweet, savory, fatty, fried, grilled, processed foods, soft/energy drinks and instant foods linked to higher MetS risk ($p < 0.05$). In non-central-obesity group, seasonings use OR=1.519 (95% CI: 1.241–1.859). In central-obesity group, sugary drinks OR=1.315 (95% CI: 1.132–1.529). Low fruit/veg intake and low physical activity also significant ($p < 0.05$).	(Permatasari et al., 2023)
Non-traditional CV risk factors: UA, HCY, HsCRP; BMI mediation; co-occurrence with overweight/obesity	Among 4,360 participants, 54.5% had MetS. Elevated non-traditional CVRFs associated with higher MetS risk ($P < 0.001$). BMI mediated 43.89% (HUA), 37.34% (HHCY), 30.99% (HHsCRP) of associations. Combination with overweight/obesity markedly increased ORs (e.g., HUA+Overweight OR~5.86; HUA+Obese OR~6.15; HHsCRP+Obese OR~7.72).	(You et al., 2023)
MetS score association with frailty and FI trajectory	Higher MetS score increased frailty risk (HR per 1 SD = 1.205; 95% CI: 1.14–1.27) and accelerated FI trajectory (β per 1 SD = 0.113/yr; 95% CI: 0.075–0.15). Cumulative MetS score per 1 SD: OR=1.222 (95% CI: 1.133–1.319) and $\beta = 0.098/\text{yr}$ (95% CI: 0.058–0.138).	(Zeng et al., 2024)
Component prevalence and MSSS groups: SBP, WC, HDL-C	Among 68,383 adults, top abnormalities: high SBP 9.41% ($n = 6,568$), high WC 8.13% ($n = 6,120$), SBP+WC co-occurrence 6.33% ($n = 4,622$). Low HDL-C associated with presence of all five components. MSSS ≥ 3 : MetS prevalence in men peaked; women increased rapidly at 40–60 yrs.	(Zhao et al., 2023)
BMI, smoking index, physical activity, alcohol, diet	Using JIS criteria prevalence 19.5%; NCEP/ATP III 10.7%; IDF 11.0%. Factors associated: age 30–79, overweight and Grade 1–3 obesity, smoking index 200–400 and >400, moderate/poor physical activity.	(Anggraini K., 2024)

fruits & vegetables		
Dietary patterns: healthy, western, traditional	Healthy pattern highest adherence associated with 46% lower odds of MetS (highest vs lowest quintile OR=0.54). Inversely associated with high glucose, WC, BP. Western/traditional patterns not significant after adjustment.	(Kheirandish et al., 2024)
Overweight/obesity, physical exercise, macronutrient intake	Overweight OR=2.4 (95% CI:1.176–3.320); Obesity OR=4.4 (95% CI:3.345–5.740). Less exercise OR=1.5 (95% CI:1.034–2.109). Fat intake Q2 protective (30% reduction, 95% CI:0.505–0.972); Carb intake Q2 increased risk OR=1.5 (95% CI:1.063–2.241).	(Rahmawati et al., 2024)
Anthropometric/metabolic indexes: LAP, WHtR, conicity, TyG, BMI, WWI, VAI, ABSI	All eight indexes positively correlated with MetS (adjORs): LAP 35.69, WHtR 29.27, conicity 11.58, TyG 5.53, BMI 3.88, WWI 3.23, VAI 2.11, ABSI 1.71. WHtR best in men (AUC 0.91, cutoff 0.53); LAP best in women (AUC 0.89, cutoff 28.67).	(Yang et al., 2024)
Physical inactivity, sedentary time, alcohol, tobacco	High metabolic comorbidity: 34% overall (25% men, 41% women). Physical inactivity OR=1.26 (95% CI:1.17–1.36); high sedentary time OR=1.24 (95% CI:1.11–1.33); alcohol use OR=1.40 (95% CI:1.23–1.53); tobacco use inversely associated OR=0.75 (95% CI:0.71–0.81).	(Sultana et al., 2024)
Age, ethnicity, elevated liver enzymes (AST, GGT)	The overall prevalence of MetS was 35.9% (95% CI: 31.4–40.6), corresponding to approximately 8.5 million Malaysian adults. The risk of MetS increased significantly with advancing age. Indian ethnicity showed a higher likelihood of developing MetS (aOR = 2.24; 95% CI: 1.19–4.22). Elevated levels of aspartate aminotransferase (AST) (aOR = 3.09; 95% CI: 1.50–6.35) and gamma-glutamyl transferase (GGT) (aOR = 3.30; 95% CI: 1.84–5.92) were identified as independent predictors of MetS.	(Wan et al., 2025)

DISCUSSION

The synthesis of evidence presented the complex, multidimensional nature of metabolic syndrome (MetS), underscoring that its etiology extends well beyond isolated biochemical

abnormalities and involves inter-related anthropometric, behavioural, dietary, inflammatory and socioeconomic factors.

Obesity and Adiposity: The Central Node

Obesity—particularly central or visceral adiposity—emerged consistently as one of the strongest determinants of MetS across multiple studies. Elevated BMI, waist circumference (WC), and waist-to-height ratio (WHtR) translated into substantially higher odds of developing MetS. Mechanistically, obesity triggers a chronic low-grade inflammatory state in adipose tissue, causing dysregulated secretion of adipokines and free fatty acids that promote insulin resistance and lipid abnormalities. Multiple studies consistently support this, providing strong evidence for its pivotal role. (Odoh et al., 2021) identified central obesity as a fundamental criterion in defining metabolic syndrome, while A. Visceral adipose tissue is crucial in promoting insulin resistance and metabolic dysfunction. Visceral fat releases pro-inflammatory cytokines and adipokines that disrupt normal metabolic balance (Verbovoy et al., 2021). The excessive fat accumulation activates immune responses, creating a chronic inflammatory environment (Susca et al., 2024). As dysfunctional adipocytes accrue, they recruit macrophages and other immune cells, raising systemic inflammation (e.g., IL-6, CRP) and impairing insulin signalling, thereby setting the stage for the typical MetS cluster of hypertension, dysglycaemia, dyslipidaemia and central obesity (Chen et al., 2021; Susca et al., 2024). In light of this, the strong associations of obesity metrics with MetS in the reviewed studies underscore the importance of weight and fat-distribution management in preventive strategies.

Physical Inactivity and Sedentary Behaviour

Physical inactivity and prolonged sedentary behavior have emerged as major determinants of metabolic syndrome (MetS). These lifestyle patterns not only contribute to excess fat accumulation but also initiate a series of metabolic disturbances, including insulin resistance, chronic low-grade inflammation, and adverse lipid alterations (Melo et al., 2021). This review showed that individuals who spend more time in sedentary activities have a 73% higher risk of developing MetS compared to those who are more active. Remarkably, this association persists even after adjusting for physical activity levels, suggesting that regular exercise alone may not be sufficient to counteract the detrimental effects of extended sitting (Kerr & Booth, 2022).

Mechanistically, prolonged sitting reduces skeletal muscle glucose uptake, impairs insulin sensitivity, and increases oxidative stress and inflammation. These physiological changes promote fat deposition, particularly in the abdominal region and liver (hepatic steatosis), thereby amplifying metabolic dysfunction (Kerr & Booth, 2022). Large-scale studies further confirm that sedentary lifestyles are associated with increased body fat accumulation, disrupted adipokine signaling, and reduced muscle metabolic capacity (Mandili et al., 2022). The consequences extend beyond metabolism, affecting cardiovascular structure and endothelial function. Sedentary behavior perpetuates a self-reinforcing cycle in which inactivity exacerbates metabolic impairment, while metabolic dysfunction further limits physical movement. Reducing sedentary time—alongside promoting regular physical activity—should therefore be regarded as a fundamental strategy in preventing and managing metabolic syndrome prevalence.

Dietary Patterns and Nutritional Intake

The role of diet—both in patterns and macronutrient composition—was also prominent. Systematic reviews show that healthy/prudent dietary patterns. In contrast, Western/unhealthy patterns (Ushula et al., 2022; Wang et al., 2023). These outcomes align with our results: higher adherence to healthy patterns was protective, while the modern dietary trend elevated risk. The underlying mechanisms include improved insulin sensitivity, lower inflammatory burdens, and favourable lipid profiles among those following healthy diets (Ushula et al., 2022; Wan et al., 2025). Nutritional influences may act both directly (e.g., via glucose/lipid metabolism) and indirectly (through body-weight control and adiposity). These findings highlight diet as a modifiable, high-impact prevention target (Kheirandish et al., 2024).

Inflammation and Non-Traditional Biomarkers

Another deeper layer of risk comes from biochemical and inflammatory biomarkers. Several studies found that elevated markers—such as uric acid, homocysteine, high-sensitivity C-reactive protein (HsCRP)—were strongly predictive of MetS onset, and that obesity mediated a substantial proportion of those associations (Ramoni et al., 2024). These observations reflect a pathophysiological continuum in which metabolic stress, adipose-derived inflammation, oxidative stress, and insulin resistance converge. The phenomenon of chronic inflammation in obesity and its role in metabolic disease has been comprehensively reviewed (Kittelson et al., 2024; Pritzker, 2023). This deeper mechanistic insight provides biological plausibility for the epidemiological associations identified and signals opportunities for biomarker-guided screening in high-risk populations.

Socioeconomic and Demographic Factors

The research also indicates that demographic and socioeconomic factors (age, gender, education, residence) modify MetS risk. For example, older age and male sex repeatedly appeared as risk enhancers, while lower education and urban residence in some contexts increased vulnerability. (Mashala et al., 2024; Saki et al., 2022) These modifiers likely reflect cumulative exposure to risk behaviours, environmental stressors, and differential access to health resources. The interactions seen in this review such as stronger effects in men or younger age groups—illustrate how prevention strategies must be tailored by subgroup rather than one-size-fits-all (González-Rocha et al., 2024).

Integrated Implications and Prevention Focus

Taken together, the evidence paints a clear picture: MetS results from a web of inter-linked determinants—excess adiposity, sedentary lifestyle, poor diet, biochemical dysfunction, and adverse socioeconomic context. Prevention strategies must be multi-faceted, emphasising weight and fat-distribution control, reduction of sedentary time irrespective of physical activity, adoption of healthy dietary patterns, and targeted screening using biomarkers. Importantly, the synergy among risk factors means that addressing one domain (e.g., diet) may moderate others (e.g., adiposity, inflammation).

Limitations and Future Directions

Despite robust associations, causality remains difficult to ascertain given the preponderance of cross-sectional designs in many studies. Longitudinal and intervention studies are still relatively scarce, particularly in diverse populations. Heterogeneity in MetS definitions and

measurement of lifestyle exposures further complicates synthesis. Future research should emphasise standardized metrics, extended follow-up and interventions that integrate multiple lifestyle domains.

CONCLUSION

This scoping review synthesizes evidence across multiple studies examining the determinants of metabolic syndrome (MetS) in adults. The findings clearly demonstrate that MetS arises from an interwoven network of biological, behavioral, and environmental factors rather than from isolated physiological abnormalities. Central obesity remains the most dominant contributor, serving as a biological hub through which insulin resistance, lipid imbalance, and chronic low-grade inflammation converge to trigger the syndrome. Physical inactivity and prolonged sedentary time further exacerbate metabolic risk, even among individuals with normal body weight, highlighting the independent contribution of movement quality and daily activity patterns to metabolic regulation. Dietary factors play a similarly pivotal role. Adherence to nutrient-rich, plant-based dietary patterns—such as Mediterranean or traditional Asian diets—was consistently associated with a lower risk of MetS, while Westernized diets high in processed meats, refined carbohydrates, and sugary or fried foods amplified susceptibility. The influence of inflammatory biomarkers such as uric acid, homocysteine, and C-reactive protein suggests that chronic inflammation and oxidative stress are key mechanistic pathways linking lifestyle behaviors to metabolic dysfunction. Furthermore, socioeconomic conditions, age, and sex disparities shape both exposure and response to these risk factors, implying that context-sensitive and population-specific prevention strategies are essential. Collectively, these findings reinforce the view of MetS as a systemic condition—reflecting the cumulative burden of unhealthy behaviors, metabolic stress, and structural inequities—requiring equally comprehensive solutions.

REFERENCES

- Ali, N., Samadder, M., Shourove, J. H., Taher, A., & Islam, F. (2023). Prevalence and factors associated with metabolic syndrome in university students and academic staff in Bangladesh. *Scientific Reports*, *13*(1), 19912. <https://doi.org/10.1038/s41598-023-46943-x>
- Anggraini K, K. S. (2024). Cross-Sectional Population Studies: Prevalence Of Metabolic Syndrome And Associated Risk Factors Among Men In Indonesia. *Proceedings of the International Conference of Public Health*, *9*(1). <https://www.proceedings.tiikmpublishing.com/index.php/icoph/article/view/1601>
- Chen, Y., Dabbas, W., Gangemi, A., Benedetti, E., Lash, J., Finn, P. W., & Perkins, D. L. (2021). Obesity Management and Chronic Kidney Disease. *Seminars in Nephrology*, *41*(4), 392–402. <https://doi.org/10.1016/j.semnephrol.2021.06.010>
- Dhondge, R. H., Agrawal, S., Patil, R., Kadu, A., & Kothari, M. (2024). A Comprehensive Review of Metabolic Syndrome and Its Role in Cardiovascular Disease and Type 2 Diabetes Mellitus: Mechanisms, Risk Factors, and Management. *Cureus*. <https://doi.org/10.7759/cureus.67428>
- González-Rocha, A., Ortiz-Rodríguez, M. A., Salazar-Torres, B. L., Muñoz-Aguirre, P., Armenta-Girado, B. I., Campos-Nonato, I., Barquera, S., & Denova-Gutiérrez, E. (2024). Association between sociodemographic factors and metabolic syndrome in

- Mexican older adults. *Salud Pública de México*, 66(3, may-jun), 267–276. <https://doi.org/10.21149/15321>
- Kerr, N. R., & Booth, F. W. (2022). Contributions of physical inactivity and sedentary behavior to metabolic and endocrine diseases. *Trends in Endocrinology & Metabolism*, 33(12), 817–827. <https://doi.org/10.1016/j.tem.2022.09.002>
- Kheirandish, M., Dastsouz, F., Azarbad, A., Mohsenpour, M. A., & Javdan, G. (2024). *The association between dietary patterns and metabolic syndrome among Iranian adults , a cross-sectional population-based study (findings from Bandare-Kong non-communicable disease cohort study)*. 7, 1–10.
- Kittelson, K. S., Junior, A. G., Fillmore, N., & da Silva Gomes, R. (2024). Cardiovascular-kidney-metabolic syndrome – An integrative review. *Progress in Cardiovascular Diseases*, 87, 26–36. <https://doi.org/10.1016/j.pcad.2024.10.012>
- Kou, L., Sun, J., Wu, P., Cheng, Z., Zhou, P., Li, N., Cheng, L., Xu, P., Xue, Y., Tian, J., & Chen, W. (2024). Associations of dietary pattern, insulin resistance and risk of developing metabolic syndrome among Chinese population. *PLOS ONE*, 19(8), e0308090. <https://doi.org/10.1371/journal.pone.0308090>
- Mandili, I. M., Balobaid, A. N., Alzahrani, H. H., Almalki, M. A., Alghamdi, A. A., Alaradi, R. R., Fallatah, H. B., Alzahrani, W. H., Alamri, H. Z., & Eid, S. S. (2022). Types of chronic diseases associated with sedentary behaviour and physical inactivity. *International Journal Of Community Medicine And Public Health*, 9(10), 3965. <https://doi.org/10.18203/2394-6040.ijcmph20222388>
- Mashala, D. G., Ntimana, C. B., Seakamela, K. P., Mashaba, R. G., & Maimela, E. (2024). Sociodemographic Disparities in the Prevalence of Metabolic Syndrome in Rural South Africa: An Analysis of Gender, Age, and Marital, Employment, and Educational Status. *Obesities*, 4(4), 480–490. <https://doi.org/10.3390/obesities4040038>
- Melo, E. A. S. de, Ferreira, L. E. de S., Cavalcanti, R. J. F., Botelho Filho, C. A. de L., Lopes, M. R., & Barbosa, R. H. de A. (2021). Nuances between sedentary behavior and physical inactivity: cardiometabolic effects and cardiovascular risk. *Revista Da Associação Médica Brasileira*, 67(2), 335–343. <https://doi.org/10.1590/1806-9282.67.02.20200746>
- Mohamed, S. M., Shalaby, M. A., El-Shiekh, R. A., El-Banna, H. A., Emam, S. R., & Bakr, A. F. (2023). Metabolic syndrome: risk factors, diagnosis, pathogenesis, and management with natural approaches. *Food Chemistry Advances*, 3, 100335. <https://doi.org/10.1016/j.focha.2023.100335>
- Odoh, G., Uwakwe, J. N., Edah, J. O., Ojobi, J. E., & Chuhwak, E. K. (2021). The Role of Central Obesity in the Pathophysiology of Metabolic Syndrome. In *New Frontiers in Medicine and Medical Research Vol. 10* (pp. 180–187). Book Publisher International (a part of SCIENCEDOMAIN International). <https://doi.org/10.9734/bpi/nfmmr/v10/12377D>
- Permatasari, M. J., Syaury, A., Noer, E. R., Pramono, A., & Tjahjono, K. (2023). Association of food consumption and physical activity with metabolic syndrome according to central obesity status in Indonesian adults: A cross-sectional study. *Jurnal Gizi Indonesia (The Indonesian Journal of Nutrition)*, 12(1), 31–35. <https://doi.org/10.14710/jgi.12.1.31-35>
- Pritzker, K. P. H. (2023). Blood-based biomarkers of chronic inflammation. *Expert Review of Molecular Diagnostics*, 23(6), 495–504. <https://doi.org/10.1080/14737159.2023.2215928>
- Rahmawati, N. D., Andriani, H., Wirawan, F., Farsia, L., Waits, A., & Karim Taufiqurahman,

- K. A. (2024). Body mass index as a dominant risk factor for metabolic syndrome among Indonesian adults: a 6-year prospective cohort study of non-communicable diseases. *BMC Nutrition*, *10*(1), 43. <https://doi.org/10.1186/s40795-024-00856-8>
- Ramoni, D., Liberale, L., & Montecucco, F. (2024). Inflammatory biomarkers as cost-effective predictive tools in metabolic dysfunction-associated fatty liver disease. *World Journal of Gastroenterology*, *30*(47), 5086–5091. <https://doi.org/10.3748/wjg.v30.i47.5086>
- Saki, N., Hashemi, S. J., Hosseini, S. A., Rahimi, Z., Rahim, F., & Cheraghian, B. (2022). Socioeconomic status and metabolic syndrome in Southwest Iran: results from Hoveyze Cohort Study (HCS). *BMC Endocrine Disorders*, *22*(1), 332. <https://doi.org/10.1186/s12902-022-01255-5>
- Subías-Perié, J., Navarrete-Villanueva, D., Fernández-García, Á. I., Moradell, A., Gesteiro, E., Pérez-Gómez, J., Ara, I., Vicente-Rodríguez, G., Casajús, J. A., & Gómez-Cabello, A. (2022). Prevalence of Metabolic Syndrome and Association with Physical Activity and Frailty Status in Spanish Older Adults with Decreased Functional Capacity: A Cross-Sectional Study. *Nutrients*, *14*(11), 2302. <https://doi.org/10.3390/nu14112302>
- Sultana, S., Nomura, S., Sheng, C. F., & Hashizume, M. (2024). Lifestyle Differences in the Metabolic Comorbidity Score of Adult Population From South Asian Countries: A Cross-Sectional Study. *AJPM Focus*, *3*(6), 100273. <https://doi.org/10.1016/j.focus.2024.100273>
- Susca, N., Leone, P., Prete, M., Cozzio, S., & Racanelli, V. (2024). Adipose failure through adipocyte overload and autoimmunity. *Autoimmunity Reviews*, *23*(3), 103502. <https://doi.org/10.1016/j.autrev.2023.103502>
- Ushula, T. W., Mamun, A., Darssan, D., Wang, W. Y. S., Williams, G. M., Whiting, S. J., & Najman, J. M. (2022). Dietary patterns and the risks of metabolic syndrome and insulin resistance among young adults: Evidence from a longitudinal study. *Clinical Nutrition*, *41*(7), 1523–1531. <https://doi.org/10.1016/j.clnu.2022.05.006>
- Verbovoy, A. F., Verbovaya, N. I., & Dolgikh, Y. A. (2021). Obesity is the basis of metabolic syndrome. *Obesity and Metabolism*, *18*(2), 142–149. <https://doi.org/10.14341/omet12707>