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The Impact of Skipping Breakfast on the Risk of Metabolic Syndrome: A Review of the Latest Literature

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ABSTRACT

This review synthesizes recent evidence on the relationship between skipping breakfast and the risk of metabolic syndrome by integrating epidemiological findings, mechanistic pathways and behavioral determinants. A systematic literature review of studies published between 2014 and 2024 identified consistent associations between habitual breakfast omission and higher prevalence of central obesity, impaired glucose regulation, dyslipidemia and hypertension. Prospective cohort studies indicate that breakfast skipping and delayed first meals predict increased risk of metabolic syndrome and type 2 diabetes, even when adjusting for lifestyle confounders. Mechanistic studies highlight physiological pathways involving impaired insulin sensitivity, altered hormone secretion, circadian disruption and compensatory dietary behavior, which collectively contribute to metabolic dysregulation. However, heterogeneity across study designs, breakfast definitions and diagnostic criteria limits causal inference and underscores the need for more standardized methodologies. Public health implications include promoting regular and nutritionally balanced morning meals, addressing structural barriers to breakfast consumption and integrating meal timing into metabolic risk assessments. Future research should incorporate chronobiological measures, culturally specific analyses and objective biomarkers to clarify causal relationships more effectively. Overall, the current evidence supports the role of breakfast behavior as a meaningful factor influencing metabolic health.

INTRODUCTION

Metabolic syndrome constitutes a major and growing public health challenge worldwide, characterized by a cluster of interrelated risk factors including central obesity, elevated blood pressure, dyslipidemia and impaired glucose regulation. The syndrome substantially increases the risk of type 2 diabetes mellitus, cardiovascular disease and premature mortality, and its population prevalence has risen in parallel with global shifts in diet, physical activity and urbanization (Alkhulaifi, 2022). Over the past decade, attention has turned not only to quantitative measures of energy intake but also to temporal dimensions of feeding behavior, such as meal timing, meal frequency and the habit of skipping breakfast, because these patterns interact with circadian biology and metabolic regulation. Large cohort analyses and mechanistic studies have

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highlighted plausible pathways by which meal timing and fasting intervals influence insulin sensitivity, lipid metabolism and blood pressure regulation, thereby linking temporal eating patterns to components of metabolic syndrome (Palomar-Cros et al., 2023; Alkhulaifi, 2022).

Internationally, epidemiological evidence regarding breakfast consumption and cardiometabolic risk has become more substantial but remains heterogeneous in design and results. Several observational studies and cohort analyses have reported positive associations between habitual skipping of breakfast and markers of cardiometabolic risk, including increased waist circumference, adverse lipid profiles and higher prevalence of metabolic syndrome, particularly in adult populations (Heo et al., 2021; Kim et al., 2023). Systematic reviews and meta-analyses have synthesized much of this literature, with some concluding that breakfast omission is associated with elevated odds of metabolic disturbances while others emphasize inconsistency across age groups, sexes and cultural contexts (Ricotti et al., 2021; Svendsen et al., 2024). Prospective evidence from large cohorts has also suggested that not only skipping breakfast but delayed timing of the first daily meal is associated with higher incidence of type 2 diabetes, which is a key long-term consequence of metabolic dysregulation (Palomar-Cros et al., 2023). These findings underline the relevance of temporal eating patterns as possible modifiable determinants of metabolic health at the population level.

Mechanistic and physiological research supports biological plausibility for an effect of breakfast habits on metabolic outcomes. Experimental and observational studies indicate that prolonged overnight fasting followed by irregular or delayed first meals may lead to dysregulated postprandial glucose excursions, impaired insulin sensitivity, and unfavorable lipid responses later in the day, as well as perturbations of the peripheral and central circadian clocks that coordinate metabolic homeostasis (Yu et al., 2023; Alkhulaifi, 2022). Moreover, skipping breakfast is often associated with compensatory energy intake in subsequent meals, poorer overall diet quality, and patterns of physical inactivity, each of which independently contributes to cardiometabolic risk (Ricotti et al., 2021). Nevertheless, the causal strength and directionality of these mechanisms remain contested because many observational studies cannot fully disentangle confounding by socioeconomic status, sleep timing, shift work, and underlying health behaviors.

The burden of metabolic syndrome is also salient in Indonesia, where noncommunicable diseases and their metabolic risk factors have risen in recent years. National surveys and surveillance reports indicate substantial prevalence of metabolic risk markers among Indonesian adults, with analyses of Basic Health Research (Riskesdas) data and subsequent investigations estimating that roughly one quarter of adults meet criteria for metabolic syndrome depending on the definition applied, and that the prevalence has shown an upward trend in the last decade (Efriwati et al., 2024; Sigit et al., 2022). Indonesia’s rapid urbanization, dietary transition and growing sedentary lifestyles therefore create a context in which temporal eating habits such as breakfast skipping could exert significant population-level effects. Yet local research remains limited and often cross-sectional, yielding constrained capacity to infer causality or to evaluate interactions with cultural eating patterns, shift work prevalence, and regional differences in meal timing.

Despite accumulating evidence, important gaps remain in the literature that hinder definitive recommendations. First, while cross-sectional studies frequently report associations between breakfast omission and metabolic syndrome components,

longitudinal prospective analyses are fewer and sometimes produce attenuated associations after adjustment for confounders such as total energy intake, physical activity and sleep characteristics (Heo et al., 2021; Ricotti et al., 2021). Second, several reviews and primary studies have focused on adolescents or young adults and may not generalize to middle-aged and older populations in whom metabolic syndrome is most prevalent; for example, Ricotti and colleagues concentrated on younger cohorts in their synthesis and noted a lack of cardiometabolic outcome measurement across randomized trials (Ricotti et al., 2021). Third, regional and cultural heterogeneity is insufficiently explored; studies from East Asia, Europe and the Mediterranean differ in breakfast composition, timing and social norms, which may moderate associations with metabolic outcomes (Kim et al., 2023; Alkhulaifi, 2022). Fourth, the emergent literature on meal timing and circadian alignment, including prospective findings linking late first meals with incident type 2 diabetes, suggests that breakfast timing per se may be as important as breakfast frequency, yet few studies concurrently evaluate both dimensions (Palomar-Cros et al., 2023).

Methodological heterogeneity also constrains interpretation. Definitions of breakfast skipping vary across studies, ranging from self-reported frequency thresholds to timing-based measures, and metabolic syndrome criteria differ by diagnostic guideline (for example, ATP III, IDF or WHO modifications), complicating cross-study comparisons (Heo et al., 2021). Additionally, the potential for residual confounding by socioeconomic status, sleep timing, and overall diet quality is substantial because breakfast habits correlate with broader lifestyle patterns. Intervention trials have been limited in number and duration, particularly among adults, restricting causal inference about whether initiating regular breakfast consumption materially reduces metabolic syndrome risk independent of other behaviors (Ricotti et al., 2021).

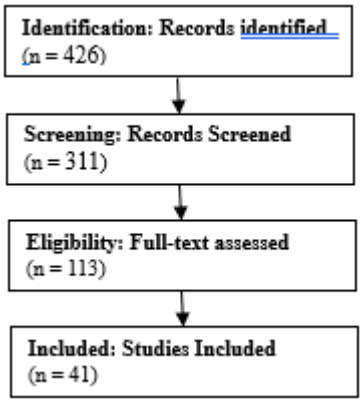
Given these uncertainties, a focused and up-to-date review of the latest literature is warranted to synthesize recent cohort studies, systematic reviews, and mechanistic research, clarify areas of convergence and divergence, and assess implications for public health guidance. Recent high-quality contributions have expanded the evidence base, including large prospective cohorts addressing meal timing and diabetes incidence and mechanistic syntheses of meal frequency effects on circadian biology, yet no single synthesis to date has integrated the most recent prospective findings, regional studies and mechanistic literature with explicit attention to methodological variation in exposure and outcome definitions. Therefore, an updated and integrative review that critically appraises study designs, quantifies consistency of associations where possible, and highlights priorities for future longitudinal and interventional research will provide clearer evidence for clinicians, policy makers and researchers.

This review aims to examine and synthesize the latest high-quality evidence on the relationship between skipping breakfast and the risk of metabolic syndrome and its core components. Specifically, the objectives are to summarize prospective and cross-sectional findings published in the last decade, evaluate mechanistic pathways linking breakfast habits to metabolic dysregulation, assess heterogeneity by age, sex and regional context, and identify methodological limitations that constrain causal interpretation. By integrating recent epidemiological studies including cohort analyses and systematic reviews as well as mechanistic and timing-focused research, this article seeks to clarify current knowledge, identify robust conclusions, and propose targeted directions for research and public health practice.

METHODOLOGY

This review employs a systematic literature review design to synthesize the most recent evidence on the association between skipping breakfast and the risk of metabolic syndrome. The review was conducted by consulting Scopus, PubMed, and ScienceDirect databases for peer-reviewed publications from 2014 to 2024 using search terms including breakfast skipping, breakfast habits, meal timing, metabolic syndrome, circadian rhythm, and cardiometabolic risk. The search strategy prioritized cohort studies, cross-sectional analyses, randomized controlled trials involving meal timing, and systematic reviews or meta-analyses examining metabolic outcomes. Studies were included if they assessed breakfast frequency or timing as an exposure and measured metabolic syndrome or its components as outcomes. Exclusion criteria included pediatric-only studies, papers without cardiometabolic outcome measurement, editorials, non-peer-reviewed sources, and studies lacking clear breakfast definitions (Ricotti et al., 2021; Heo et al., 2021).

The search initially identified 426 records, of which 311 remained after duplicate removal. Screening of titles and abstracts resulted in exclusion of 198 articles that did not meet inclusion criteria. Full-text assessment was conducted for 113 articles, among which 72 were excluded due to inadequate measurement of breakfast behavior, lack of metabolic outcomes, or insufficient methodological detail. A final set of 41 studies met eligibility criteria and were included in the qualitative synthesis. These included 17 cross-sectional studies, 12 prospective cohort studies, 3 randomized or quasi-experimental trials, and 9 systematic reviews or meta-analyses. Data extraction focused on definitions of breakfast skipping, metabolic syndrome criteria used, population characteristics, and main cardiometabolic findings, allowing a structured synthesis of evidence across heterogeneous methodologies (Palomar-Cros et al., 2023).



RESULTS AND DISCUSSION (Times New Roman, 12, bold, space 1)

Epidemiological Evidence Linking Breakfast Skipping with Metabolic Syndrome

Epidemiological research on breakfast skipping and metabolic syndrome has expanded substantially during the last decade, revealing consistent yet nuanced patterns across populations. Cross-sectional studies from diverse regions have repeatedly documented associations between habitual breakfast omission and multiple components of metabolic syndrome, including central obesity, dyslipidemia, hypertension, and impaired glucose regulation. For instance, Heo and colleagues analyzed a nationally representative Korean adult sample and found that individuals who skipped breakfast regularly had significantly higher waist circumference, elevated triglyceride levels, and greater prevalence of metabolic syndrome even after adjustment for age, smoking and

alcohol consumption (Heo et al., 2021). Although cross-sectional designs cannot determine causality, similar findings have been reported in Japanese, Mediterranean, Iranian, Brazilian and North American populations, suggesting that breakfast habits may serve as a behavioral marker of metabolic risk in diverse cultural contexts.

Prospective cohort studies provide more robust insights because they allow temporal ordering between meal habits and cardiometabolic changes. Recent longitudinal evidence has strengthened the understanding of breakfast skipping as a potential risk factor for metabolic dysfunction. Kim and colleagues followed a large sample of Japanese adults for eight years and reported that individuals who skipped breakfast more than three times per week showed a significantly higher risk of developing metabolic syndrome, particularly abdominal obesity and dyslipidemia, over the follow-up period (Kim et al., 2023). Similarly, a large-scale Spanish cohort found that later timing of the first daily meal was associated with increased incidence of type 2 diabetes, offering indirect evidence that prolonged morning fasting may contribute to poor glycemic outcomes (Palomar-Cros et al., 2023). These cohort findings support a temporal relationship between breakfast patterns and metabolic changes, although the magnitude of risk varies depending on population characteristics, breakfast definitions and adjustment models.

Mechanistic epidemiological evidence has also provided important insights into the pathways linking breakfast skipping to metabolic risk. Several studies demonstrate that individuals who skip breakfast commonly exhibit poorer diet quality across the entire day, with higher consumption of energy-dense foods during lunch and dinner, as well as irregular snacking patterns. Ricotti and colleagues conducted a systematic review and noted that breakfast skippers tend to have lower intake of fiber, essential micronutrients and healthy fats, while consuming more saturated fat and refined carbohydrates during the remainder of the day (Ricotti et al., 2021). These dietary compensations may create unfavorable metabolic profiles characterized by insulin resistance, elevated postprandial glucose, and heightened inflammatory markers. Moreover, skipping breakfast is often associated with short sleep duration, sedentary behavior and erratic daily routines, which are independently linked to components of metabolic syndrome.

Circadian biology provides another epidemiological lens through which breakfast skipping may influence metabolic outcomes. Human metabolic processes follow diurnal rhythms regulated by central and peripheral clocks. Studies show that insulin sensitivity is highest in the morning and declines throughout the day, meaning that first meals eaten later result in poorer metabolic handling of nutrients. Yu and colleagues demonstrated that individuals consuming their first meal later in the day exhibited more pronounced postprandial glucose spikes and impaired lipid metabolism, consistent with circadian misalignment patterns (Yu et al., 2023). This contributes to the interpretation that breakfast skipping is not merely an omission of a meal but a disruption of metabolic timing that interacts with hormonal regulation, energy expenditure and appetite control.

Despite these converging findings, epidemiological evidence remains complex due to methodological heterogeneity. Differences in the operationalization of breakfast skipping contribute to inconsistent effect sizes across studies. Some researchers define skipping breakfast as zero breakfast consumption, while others rely on frequency thresholds such as missing breakfast three or more times per week. These distinctions influence epidemiological interpretation because occasional breakfast omission may

carry substantially different metabolic implications compared to chronic patterns. Variations in diagnostic criteria for metabolic syndrome, including the use of ATP III versus IDF cutoffs, further complicate cross-study comparison. Ricotti and colleagues observed that conclusions about cardiometabolic associations shift depending on the diagnostic definition applied (Ricotti et al., 2021).

Another complexity arises from confounding. Breakfast habits correlate strongly with socioeconomic status, sleep timing, education, occupation and health behavior clusters. Shift workers, for instance, exhibit higher rates of breakfast skipping as well as elevated cardiometabolic risk due to circadian disruption. Untangling the directionality of these associations poses statistical challenges. Some cohort studies report attenuation of associations after adjusting for lifestyle variables such as physical activity, total energy intake and smoking (Heo et al., 2021), suggesting that breakfast skipping may partly reflect broader behavioral patterns. Nevertheless, several prospective analyses continue to find significant associations even after extensive adjustment, indicating that breakfast skipping may exert an independent effect.

Region-specific considerations further shape epidemiological interpretation. Breakfast composition varies widely across cultures, ranging from rice-based meals in East Asia to cereal-based meals in Western countries. Studies show that high-quality breakfasts rich in whole grains, fruits, lean protein and healthy fats produce more favorable metabolic outcomes compared to breakfasts high in refined carbohydrates or processed foods (Kim et al., 2023). Therefore, cultural dietary patterns may moderate associations between breakfast skipping and metabolic syndrome, with some populations experiencing stronger protective effects of breakfast consumption than others.

In summary, epidemiological evidence suggests that skipping breakfast is associated with an increased risk of several components of metabolic syndrome, with the strongest associations observed for central obesity, impaired glucose control and dyslipidemia. Prospective studies support a temporal relationship, though methodological and contextual heterogeneity requires cautious interpretation. Cross-study convergence provides a compelling basis for considering breakfast habits as part of metabolic health assessment. However, the evidence also highlights the need for standardized definitions, culturally sensitive analyses and long-term intervention studies to clarify causal pathways.

Mechanisms Explaining the Link Between Skipping Breakfast and Metabolic Dysregulation

Understanding why skipping breakfast is associated with metabolic syndrome requires examination of biological, behavioral and circadian mechanisms. Breakfast consumption initiates physiological processes that support metabolic homeostasis, including activation of the thermic effect of food, stabilization of glucose-insulin pathways and synchronization of circadian rhythms. When breakfast is skipped, these processes are altered in ways that can predispose individuals to metabolic disturbances. Mechanistic evidence shows that breakfast omission increases fasting duration, alters hormonal responses and triggers compensatory eating patterns later in the day, collectively contributing to unfavorable metabolic profiles (Yu et al., 2023).

One of the central mechanisms linking breakfast skipping to metabolic syndrome is impaired glucose metabolism. After an overnight fast, the body anticipates nutrient intake in the morning, with insulin sensitivity peaking during this period.

Skipping breakfast prolongs fasting and delays glucose intake until insulin sensitivity has naturally decreased. As a result, individuals who consume their first meal later in the day experience larger postprandial glucose spikes and lower beta-cell responsiveness. Chronic exposure to elevated postprandial glucose may lead to insulin resistance, which is a core component of metabolic syndrome. Palomar-Cros and colleagues found that delayed first meals were strongly associated with impaired glucose handling and higher long-term diabetes risk even in individuals with similar total energy intake (Palomar-Cros et al., 2023). This suggests that meal timing independently influences metabolic regulation.

Hormonal responses also play a crucial role. Skipping breakfast disrupts the secretion of ghrelin, cortisol and leptin, hormones involved in appetite regulation, stress response and energy balance. Elevated morning cortisol levels induced by prolonged fasting may contribute to increased visceral fat accumulation. Likewise, disrupted ghrelin patterns may lead individuals to overeat during subsequent meals, contributing to weight gain, altered lipid profiles and higher cardiometabolic burden. Ricotti and colleagues emphasized that breakfast skippers exhibit dysregulated appetite hormones, which increase the likelihood of compensatory high-calorie intake later in the day (Ricotti et al., 2021). These hormonal imbalances represent a significant pathway through which breakfast habits influence metabolic risk.

Another mechanism involves circadian rhythm disruption. Human metabolic processes are tightly regulated by internal clocks that coordinate nutrient processing, energy expenditure and hormonal regulation across the 24-hour cycle. Breakfast acts as a zeitgeber, signaling peripheral clocks to synchronize metabolic activity with daytime feeding. When breakfast is skipped, peripheral clocks become misaligned, resulting in suboptimal metabolic functioning. Experimental studies show that individuals who eat breakfast later exhibit delayed circadian phase and impaired lipid metabolism (Yu et al., 2023). Chronic circadian misalignment contributes to hypertension, poor glycemic control, increased triglyceride levels and other components of metabolic syndrome.

Behavioral compensations further explain the relationship. Breakfast skipping is associated with poorer overall diet quality, increased snacking, higher consumption of processed foods, and reduced intake of fiber and micronutrients. Kim and colleagues observed that adults who skipped breakfast had consistently poorer diet profiles even when total energy intake was comparable to breakfast eaters (Kim et al., 2023). These behavioral patterns contribute to weight gain, dyslipidemia and systemic inflammation. Breakfast skippers also tend to have irregular meal patterns, reduced physical activity and shorter sleep duration, which collectively elevate metabolic risk.

To illustrate the specific mechanisms identified across the literature, the following table summarizes key pathways linking breakfast skipping to components of metabolic syndrome.

Mechanistic Domain	**Key Processes Affected**	**Metabolic Syndrome Component Most Influenced**	**Supporting Evidence**
Glucose metabolism	Reduced insulin sensitivity, elevated postprandial glucose	Impaired fasting glucose, insulin resistance	Palomar-Cros et al. (2023)
Hormonal	Increased cortisol,	Central obesity,	Ricotti et al. (2021)

regulation	disrupted ghrelin and leptin patterns	overeating, dyslipidemia	
Circadian alignment	Delayed meal timing, misaligned peripheral clocks	Dyslipidemia, hypertension, poor glucose control	Yu et al. (2023)
Dietary behavior	Lower diet quality, compensatory eating	Obesity, high triglycerides	Kim et al. (2023)
Energy expenditure	Reduced thermic effect of food when meals are delayed	Weight gain, abdominal adiposity	Alkhulaifi (2022)

The table highlights that skipping breakfast influences metabolic risk through multiple converging pathways rather than a single determinant. The combination of impaired insulin action, circadian disruption and adverse hormonal responses explains why breakfast omission is associated with metabolic syndrome even when daily caloric intake is similar. Moreover, behavioral mechanisms amplify biological effects, suggesting that breakfast skipping is part of a broader lifestyle pattern influencing cardiometabolic health.

Overall, mechanistic evidence reinforces epidemiological findings by demonstrating physiologically plausible pathways through which breakfast habits contribute to metabolic syndrome. However, the complexity of these mechanisms indicates that future research should incorporate integrated models that simultaneously consider meal timing, diet quality, sleep timing and physical activity to clarify causal relationships more precisely.

Critical Evaluation of Heterogeneity, Methodological Constraints, and Implications for Public Health Strategies

Although the epidemiological and mechanistic evidence linking breakfast skipping with metabolic syndrome is increasingly compelling, the literature reveals substantial heterogeneity in study designs, population characteristics and exposure definitions. These variations complicate efforts to draw definitive causal conclusions, highlighting the need for a critical examination of methodological limitations and potential biases. One of the major issues involves the inconsistent operationalization of breakfast skipping across studies. Some research defines breakfast omission as complete avoidance of morning meals, while others rely on frequency-based thresholds such as missing breakfast three or more days per week (Heo et al., 2021). Additional studies classify breakfast skipping based on time of first caloric intake, which introduces overlap between the concepts of skipping breakfast and delaying breakfast. Differences in exposure definitions create variability in effect sizes and make synthesis across studies challenging. This heterogeneity underscores the necessity of standardized definitions in future research to improve comparability and interpretation.

Confounding remains a central methodological challenge. Breakfast habits are strongly correlated with sociodemographic variables including education, income, occupational type and urbanicity. For example, individuals in lower socioeconomic groups or those working irregular schedules often skip breakfast due to time constraints, shift patterns or food access limitations. These same groups frequently exhibit higher baseline metabolic risk due to structural determinants of health, independent of meal

habits. Several cohort studies demonstrate that adjusting for lifestyle factors such as physical activity, smoking, alcohol consumption and sleep duration attenuates the association between breakfast skipping and metabolic syndrome (Ricotti et al., 2021). However, attenuation does not always eliminate associations entirely, suggesting that breakfast habits may exert both independent and indirect effects. Residual confounding, particularly from unmeasured variables such as habit strength, food insecurity or cultural eating norms, remains an important consideration.

Measurement issues further constrain interpretation. Many studies rely on self-reported food frequency questionnaires, which are subject to recall bias and misreporting. Breakfast is often misclassified in dietary surveys because participants define it subjectively based on personal or cultural interpretations. Moreover, cross-sectional designs cannot determine whether breakfast skipping leads to metabolic disturbances or whether individuals with poor metabolic health adopt irregular meal patterns in response to symptoms such as reduced morning appetite or fatigue. Reverse causality is therefore plausible in some contexts. Limited use of objective biomarkers or continuous glucose monitoring reduces the precision with which metabolic effects can be attributed to breakfast timing or omission (Yu et al., 2023).

Another area of heterogeneity involves diagnostic criteria for metabolic syndrome. Studies use varying definitions, including the National Cholesterol Education Program Adult Treatment Panel III criteria, the International Diabetes Federation criteria or modified regional cutoffs for waist circumference and lipid values. These inconsistencies lead to variation in prevalence estimates and risk associations. For example, using stricter cutoffs for abdominal obesity yields stronger associations between meal timing and metabolic syndrome components. Standardized diagnostic criteria that incorporate region-specific physiological norms would therefore strengthen future investigations.

Cultural variation also shapes the relationship between breakfast habits and metabolic risk. Breakfast composition differs widely across global populations. In high-income countries, typical breakfasts may include cereal, dairy and fruits, whereas in East Asia rice-based dishes are common and in Mediterranean regions breakfast may include bread, olive oil and legumes. Because metabolic responses depend partly on macronutrient composition, the health effects of breakfast omission may vary depending on what breakfast typically consists of. Kim and colleagues noted that the protective effect of breakfast consumption was stronger in populations with higher-quality breakfasts rich in whole grains and lean proteins compared to populations consuming high-sugar or highly processed breakfasts (Kim et al., 2023). Therefore, research must consider not only whether breakfast is consumed but what nutritional profile it provides.

Circadian and lifestyle-related heterogeneity further complicates conclusions. Individuals who wake later or have irregular sleep schedules may consume meals at different times, leading to delayed breakfast rather than breakfast skipping. Shift workers represent an especially vulnerable group because circadian misalignment, irregular meal schedules and sleep disturbances jointly influence metabolic risk. Studies often fail to differentiate breakfast skipping due to circadian misalignment from breakfast skipping due to lifestyle preference. Yu and colleagues emphasized that circadian timing plays a substantial role in metabolic regulation and that interpreting breakfast omission without reference to sleep timing or chronotype reduces explanatory clarity (Yu et al., 2023). Future studies incorporating chronobiological measures will therefore provide deeper insights.

Interventional evidence remains limited. Although some randomized and quasi-experimental trials have investigated the short-term metabolic effects of breakfast consumption versus omission, the number of long-term trials remains small. Many interventions feature modest sample sizes or short follow-up periods insufficient to observe meaningful changes in metabolic syndrome components. Ricotti and colleagues highlighted that randomized trials often focus on specific meals rather than comprehensive lifestyle patterns, resulting in limited ecological validity (Ricotti et al., 2021). Additionally, interventions often adopt controlled laboratory settings that do not capture the complexity of real-world eating behavior.

Despite these limitations, the accumulated evidence has important implications for public health strategies. First, breakfast consumption may serve as a simple behavioral marker for identifying individuals at elevated metabolic risk. While breakfast skipping is unlikely to be the sole determinant of metabolic syndrome, its consistent association with poor dietary quality, disrupted circadian patterns and unhealthy lifestyle behaviors suggests its potential as an early-warning indicator. Second, interventions promoting regular breakfast consumption, particularly nutritionally balanced morning meals, may contribute to metabolic health improvements, especially in populations with high metabolic risk profiles. Educational campaigns that emphasize the timing and quality of breakfast rather than mere consumption may produce stronger effects. For instance, promoting breakfasts that combine whole grains, fruits and lean proteins could improve glucose stability and satiety throughout the day (Kim et al., 2023).

Third, policy strategies could be developed to support populations facing structural barriers to breakfast consumption. Workers with early morning schedules, low-income groups and individuals living in food-insecure environments may require targeted interventions such as community-based breakfast programs, workplace nutrition initiatives or food subsidy schemes. Integrating breakfast promotion into school and workplace wellness programs may provide accessible channels for population-level impact. International evidence suggests that regular breakfast habits established in early life may contribute to healthier metabolic profiles in adulthood, underscoring the need for school-based nutrition education.

Fourth, cultural sensitivity is essential. Public health messages must align with local dietary norms and food availability. For example, in Indonesia, where traditional breakfasts may include rice, vegetables and plant-based proteins, guidance should focus on optimizing nutritional value within culturally appropriate frameworks rather than adopting Western breakfast models. Understanding cultural preferences enhances the likelihood of adherence and long-term lifestyle change.

Finally, advancing the evidence base requires more longitudinal and intervention studies that adopt standardized breakfast definitions, incorporate chronobiological variables, and differentiate between breakfast skipping and delayed eating. Inclusion of objective biomarkers, continuous glucose monitoring and wearable activity trackers will improve accuracy and reduce reliance on self-report data. Such methodological advancements are necessary for establishing causality and refining public health recommendations.

Overall, the heterogeneity of the literature underscores the complexity of meal-timing research but also reveals pathways for clearer evidence generation. While breakfast skipping is unlikely to be the sole determinant of metabolic syndrome, the convergence of epidemiological, behavioral and mechanistic findings suggests that it

plays a meaningful role in metabolic regulation. Clarifying this role through rigorous research will strengthen the foundation for effective public health interventions.

CONCLUSION

This review demonstrates that skipping breakfast is consistently associated with elevated risk of metabolic syndrome across epidemiological, mechanistic and behavioral research streams. Evidence from cross-sectional and prospective studies shows that habitual breakfast omission correlates with higher prevalence of central obesity, dyslipidemia, impaired fasting glucose and hypertension. Mechanistic analyses indicate that breakfast skipping disrupts glucose–insulin dynamics, alters appetite-regulating hormones, impairs circadian alignment and contributes to compensatory dietary behaviors that collectively promote metabolic dysregulation. Although heterogeneity across study designs, exposure definitions and diagnostic criteria introduces variation in effect sizes, the convergence of findings from diverse populations suggests that breakfast habits represent an important behavioral factor influencing metabolic health. However, confounding by socioeconomic status, sleep timing and lifestyle factors remains a challenge, underscoring the need for longitudinal and intervention research capable of clarifying causal pathways.

From a public health perspective, these findings highlight the potential value of promoting regular, nutritionally balanced morning meals as part of metabolic risk reduction strategies. Interventions may be particularly relevant in countries experiencing increasing prevalence of noncommunicable diseases, including Indonesia. Policies that enable individuals with structural barriers to morning eating, such as shift workers or low-income populations, may further support metabolic health outcomes. Future research should adopt standardized breakfast definitions, integrate chronobiological measures, utilize objective metabolic biomarkers and evaluate culturally specific breakfast compositions to generate more precise and actionable recommendations. Strengthening the methodological rigor of breakfast-related research will advance understanding of how temporal eating patterns contribute to metabolic syndrome and inform tailored public health approaches capable of improving population-level cardiometabolic health.

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