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Original scientific paper

LATE DINNER AND ITS IMPACT ON OBESITY AND METABOLIC SYNDROME

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Abstract

Meal timing is increasingly recognized as a critical determinant of metabolic health, alongside diet quality and caloric intake. Late-night eating—particularly dinner consumed close to sleep onset—has been associated with obesity, impaired glucose metabolism, and features of metabolic syndrome. This study investigated the relationship between late dinner habits and metabolic outcomes in young adults, integrating evidence from a cross-sectional survey and a comprehensive literature review. A survey with 30 adult volunteers, from Skopje, North Macedonia, aged 28–35 years, with a validated questionnaire, assessing dinner timing, dietary patterns, and self-reported health conditions; anthropometric data was completed. Among participants, 70% reported eating dinner after 21:00. Late eaters had higher prevalence of overweight (67% vs. 22% in early eaters) and metabolic conditions, including diabetes, elevated cholesterol, fatty liver, hypertension, and polycystic ovary syndrome. Most late eaters (85%) consumed high-fat or high-sugar meals. These observations align with extensive human studies showing that late meals are linked to higher body mass index, reduced insulin sensitivity, impaired glucose tolerance, dyslipidaemia, and altered energy expenditure, independent of total energy intake. Mechanistic evidence implicates circadian misalignment, disrupted secretion of appetite-regulating hormones, impaired diet-induced thermogenesis, and perturbation of gut microbiome rhythms. Behavioral and social factors such as skipping breakfast, irregular work schedules, and evening social activities further contribute to delayed meal timing. Collectively, these findings indicate that late dinner consumption is a modifiable behavioral risk factor with clinically meaningful implications. Promoting earlier, balanced dinners and aligning meal timing with the body's circadian rhythm may support metabolic health, prevent obesity, and reduce the risk of metabolic syndrome in young adults and the general population.

Keywords: eating habits, chrononutrition, circadian rhythm, caloric intake, metabolic health, BMI.

1. Introduction

The global rise in obesity and metabolic syndrome has intensified scientific interest in lifestyle-related factors that influence metabolic regulation beyond traditional determinants such as caloric intake, physical activity, and dietary composition. An expanding body of research highlights meal timing as a critical but often overlooked component of metabolic health. This concept, central to the field of chrononutrition, examines how alignment—or misalignment—between eating patterns and the body's endogenous circadian rhythms affects physiological processes and long-term disease risk (Peters et al., 2024).

The circadian system orchestrates daily fluctuations in glucose tolerance, insulin sensitivity, lipid metabolism, appetite regulation, and energy expenditure. These processes operate with highest efficiency during the biological day and decline toward evening and night. When meals, particularly dinner, are consumed late, nutrient metabolism occurs during a period characterized by reduced insulin sensitivity, diminished diet-induced thermogenesis, and impaired glucose handling (Davis et al., 2022; Peters et al., 2024). Controlled feeding studies consistently show that identical meals elicit significantly higher postprandial glucose and insulin responses when eaten in the evening compared with earlier in the day (Gu et al., 2020; P. Wang et al., 2024); Karatzi et al., 2017).

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Late-night eating, typically defined as food intake after 21:00–22:00 or within two hours before bedtime, has been linked to multiple adverse outcomes, including obesity, metabolic syndrome, cardiovascular disease, and impaired sleep quality (Gu et al., 2020; P. Wang et al., 2024). According to the World Health Organization, health encompasses not only physical but also mental and social well-being (Langevin, 2024), and disruptions to circadian alignment—such as those caused by late dinners—may undermine this balance. Epidemiological evidence demonstrates that individuals who consume a large proportion of their daily energy intake in the evening have higher BMI, poorer glucose tolerance, and increased cardiometabolic risk (Davis et al., 2022; Peters et al., 2024). For example, a cohort study of 1,245 adults showed that consuming ≥48% of daily caloric intake at dinner doubled the likelihood of obesity over six years, independent of total energy intake and physical activity. Similarly, consuming ≥33% of daily energy intake in the evening was associated with twofold higher odds of overweight/obesity (Davis et al., 2022).

Importantly, research incorporating internal circadian phase shows that meal timing relative to melatonin onset—not just clock time—is strongly associated with adiposity. In a controlled observational study, young adults with higher body fat ate meals approximately 1.1 hours closer to melatonin onset compared to lean individuals, and this timing predicted BMI and body fat percentage (McHill et al., 2017). Additional data suggest that late-night eating may disrupt appetite-regulating hormones such as leptin and ghrelin, shift substrate utilization, and alter the diurnal oscillations of the gut microbiota, further contributing to metabolic dysregulation (Peters et al., 2024).

Modern lifestyle factors, including urbanization, irregular work schedules, prolonged screen exposure, stress, and social habits, have collectively shifted eating patterns toward later in the day. Young adults, in particular, may combine late meals with sedentary behaviors, amplifying metabolic consequences (Voigt et al., 2019). Public health sources emphasize that eating "at the wrong circadian time" may reduce calories used and increase calories stored, even without increasing total intake (Johns Hopkins, 2024), whereas news sources highlight that most evidence remains associative rather than strictly causal (Lloyd, 2025).

Given increasing scientific recognition of meal timing as a determinant of metabolic health, a comprehensive synthesis of current evidence is warranted. This article reviews the relationship between late dinner habits and health outcomes among young adults, and comparing the results with existing literature. It points out the impact of late-night eating on obesity and metabolic syndrome, outlines plausible chronobiological mechanisms, and discusses potential strategies for integrating meal timing into public health and nutrition guidelines.

2. Materials and Methods

A descriptive cross-sectional survey was conducted among 30 individuals aged 28–35 years. A structured questionnaire was used to collect data on dinner timing, food types, body measurements, and the presence of digestive or metabolic health problems. Lifestyle factors such as stress, sleep habits, and physical activity were also assessed.

Body Mass Index (BMI) was calculated as weight (kg)/height (m^2). Data were analyzed descriptively to determine the frequency of late dinners and their association with overweight and health problems. Participants provided informed consent.

In addition, a structured literature search was conducted across PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar (2000–2025) to identify peer-reviewed human studies examining late dinner or late-night eating in relation to obesity, glucose and lipid metabolism, insulin sensitivity, circadian misalignment, and metabolic syndrome. Search terms combined MeSH and keywords such as "late dinner," "late-night eating," "chrononutrition," "meal timing," "circadian rhythm," "obesity," and "cardiometabolic risk" using Boolean operators.

Eligible studies included observational designs, randomized and controlled feeding trials, cross-sectional studies, and systematic reviews reporting metabolic outcomes, while animal studies, case reports, and articles unrelated to dinner timing were excluded.

3. Results of the survey

Of the 30 surveyed participants, 21 individuals (70%) reported eating late dinners, defined as consuming their main evening meal after 21:00, whereas 9 participants (30%) ate earlier. Late dinner consumption was strongly associated with higher body weight. Among late eaters, 14 participants (66.7%) were classified as overweight, compared with only 2 individuals (22.2%) in the early-dinner group. BMI values among late eaters ranged widely, with several respondents showing BMI levels consistent with overweight or obesity (e.g., 31.5, 33.7, 33.6, 33.2) (Table 1).

Table 1. Participant Dinner Timing, BMI, and Reported Health Conditions

Respondent	**Dinner Timing**	**BMI**	**Health Condition**
1	Early	26.2	None
2	Early	26.3	None
3	Late	27.3	None
4	Early	21.2	None
5	Late	20.9	None
6	Late	25.9	None
7	Late	27.7	Diabetic
8	Late	31.5	Elevated Cholesterol
9	Late	33.7	None
10	Late	33.6	Fatty Liver
11	Late	33.6	None
12	Late	21.6	Polycystic Ovary Syndrome
13	Early	21.3	None
14	Early	20.6	None
15	Late	24.6	High Blood Pressure
16	Late	27.2	Polycystic Ovary Syndrome
17	Late	19.1	None
18	Late	24.2	Diabetic
19	Late	24.8	None
20	Late	24.8	Elevated Cholesterol
21	Late	25.2	None
22	Late	26.7	None
23	Late	23.1	Diabetic
24	Early	19.6	None
25	Late	24.3	None
26	Late	33.2	None
27	Early	25.5	None
28	Early	21.1	None
29	Late	24.5	None
30	Late	33.2	None

Health conditions were also more frequently reported among those who ate late. Nine respondents (42.9% of late eaters) reported at least one metabolic or endocrine condition,

including diabetes (3 cases), elevated cholesterol (2 cases), fatty liver disease (1 case), high blood pressure (1 case), and polycystic ovary syndrome (2 cases). In contrast, all early-dinner participants reported no diagnosed metabolic disease.

Differences were also observed in dietary patterns. The majority of late eaters (85%) reported consuming heavier or non-traditional evening meals such as fast food, fried foods, or sweets. In comparison, early eaters tended to consume lighter, nutrient-dense meals, typically consisting of soups, vegetables, or home-prepared dishes.

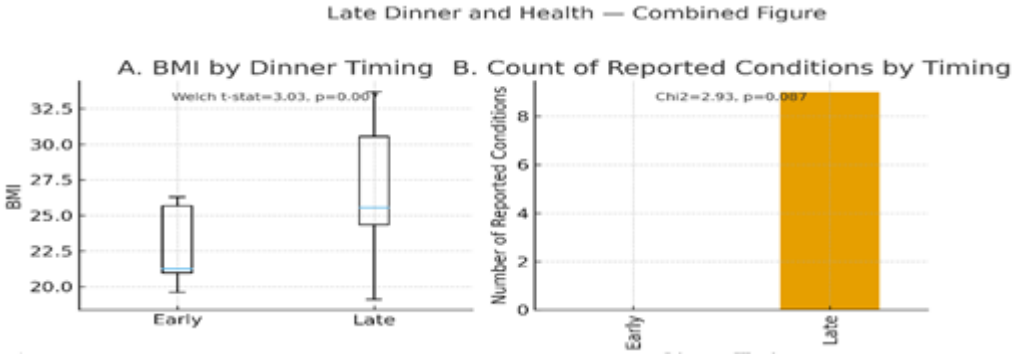

Figure 1. A. BMI by dinner timing; B. Count of reported conditions by dinner timing.

Overall, the survey indicates a clear pattern: late dinner timing was associated with higher BMI values, a greater prevalence of metabolic health issues, and less healthy food choices, whereas early eaters showed lower BMI, no reported metabolic disorders, and more balanced evening meals. These results align with existing evidence linking late-night eating to disrupted metabolic regulation and increased cardiometabolic risk.

4. Discussion

The findings of this study demonstrate a clear pattern linking late-night dinner consumption with adverse metabolic indicators in young adults. Among the 30 participants, 70% reported eating dinner after 21:00, and this group showed markedly higher rates of overweight status and self-reported metabolic conditions—including diabetes, elevated cholesterol, fatty liver, hypertension, and polycystic ovary syndrome—compared with those who ate earlier. These observations align with extensive evidence emphasizing that late meal timing contributes independently to obesity and cardiometabolic dysfunction (Garaulet & Gómez-Abellán, 2013, 2014).

Consistent with prior literature, this study reinforces that when food is consumed can significantly influence metabolic outcomes, beyond total calorie intake or diet composition. Human metabolism is strongly regulated by circadian rhythms, with insulin sensitivity, glucose tolerance, and diet-induced thermogenesis peaking earlier in the day and progressively declining toward the biological night (Jakubowicz et al., 2013; Morris et al., 2015). Late-night eating, especially meals consumed near or after dim-light melatonin onset, induces circadian misalignment, leading to elevated postprandial glucose, reduced lipid oxidation, and lower energy expenditure (McHill et al., 2017; Scheer et al., 2009). Evidence from controlled trials confirms that identical meals produce significantly higher glucose and insulin excursions when consumed late in the evening rather than earlier in the day (Karatzi et al., 2017; Poggiogalle et al., 2018).

The mechanisms underlying these effects are multifactorial. Circadian misalignment disrupts metabolic homeostasis by impairing insulin signaling, delaying triglyceride clearance, and reducing nocturnal thermogenesis. Late eating also alters the secretion of appetite-regulating hormones such as leptin and ghrelin, contributing to increased evening hunger and reduced satiety (Goel et al., 2009). Furthermore, the gut microbiome— itself exhibiting circadian

rhythmicity—may experience dysregulation in response to late meals, promoting low-grade inflammation and metabolic dysfunction (Thaiss et al., 2015). These mechanisms help explain why individuals who consume a higher proportion of daily calories at night tend to exhibit higher BMI, greater waist circumference, and increased prevalence of metabolic syndrome (Liu et al., 2017).

Behavioral and social factors also play an important role in shaping late-night eating patterns. Skipping breakfast, evening social activities, irregular work schedules, and stress are well-established predictors of delayed meal timing, particularly in younger adults (Almoosawi et al., 2016; Taetzsch et al., 2021). These determinants highlight that meal timing is not simply a matter of personal preference but emerges from a complex interplay of lifestyle, occupational, and psychosocial influences.

Table 2 summarizes key human studies linking late-night eating or dinner timing with metabolic outcomes. Observational cohorts demonstrate that consuming a large proportion of daily calories at dinner increases the odds of overweight and obesity, with long-term follow-up showing up to a 2.3-fold higher risk independent of total caloric intake (Davis et al., 2022). Controlled feeding and metabolic chamber studies provide physiological evidence that late meals reduce glucose tolerance, impair insulin sensitivity, and decrease energy expenditure (Bandín et al., 2015; Morris et al., 2015). Interventional weight-loss trials reveal that late eaters lose less weight and show poorer hormonal regulation despite comparable caloric intake (Garaulet & Gómez-Abellán, 2013; Jakubowicz et al., 2013). Together, these studies underscore that meal timing is a clinically significant, modifiable factor influencing metabolic health (Table 2).

Table 2. Key Human Studies on Late Dinner / Late Eating and Metabolic Health

Study	**Population & N**	**Study Design**	**Definition of Late Eating / Exposure**	**Outcomes Measured**	**Key Findings**	**Relevance**
(McHill et al., 2017)	110 healthy adults (18–22 yrs)	Observational (7-day monitoring)	Eating closer to *melatonin onset* (biological night)	Body fat %, BMI, circadian phase	Eating later relative to circadian phase was **significantly associated with higher body fat**. Clock-time alone did not predict adiposity; timing relative to circadian rhythm did.	Demonstrates that *biological* late meals increase adiposity.
(Davis et al., 2022)	1,245 adults	Longitudinal cohort (6 years)	≥48% of daily calories consumed at dinner vs. <48%	Obesity incidence	High dinner energy: **~2.3× higher odds of obesity** at follow-up, independent of baseline BMI and activity.	Shows strong long-term association between heavy late meals and obesity.

Study	Population & N	Study Design	Definition of Late Eating / Exposure	Outcomes Measured	Key Findings	Relevance
(J. B. Wang et al., 2014)	239 young adults	Cross-sectional/ observational studies	≥33% vs. <33% total energy after 20:00	BMI, overweight risk	Late eaters: **~2× higher odds of overweight/obesity**.	Reinforces that large late meals predict obesity even after adjusting for lifestyle factors.
(Garaulet & Gómez-Abellán, 2013)	420 adults undergoing weight-loss treatment	20-week interventional follow-up	"Late lunch eaters": main meal after 15:00	Weight loss outcomes	Late eaters lost **significantly less weight**, and had poorer insulin sensitivity markers.	Shows that late main meals impair weight reduction and metabolism.
(Jakubowicz et al., 2013)	93 overweight/obese women	RCT, 12 weeks	700 kcal meal at breakfast vs. dinner	Weight loss, insulin, ghrelin	High-calorie dinner group lost **much less weight**, had worse glucose and hunger-hormone profiles.	Demonstrates metabolic disadvantage of large evening meals.
(Morris et al., 2016)	7 healthy adults	Controlled metabolic chamber study	Meals at 20:00 vs. 13:00	Glucose, insulin sensitivity, energy expenditure	Late-eating condition had **reduced glucose tolerance** and **reduced insulin sensitivity**.	Direct physiological evidence of impaired glucose metabolism after late meals.
(Bandín et al., 2015)	32 adults	Randomized crossover	Same meals, early vs. late schedule	Resting energy expenditure, glucose tolerance	Late eating led to **lower resting energy expenditure**, higher glucose, and altered cortisol rhythm.	Mechanistic support: late dinner slows metabolism.
(Kahleova et al., 2017)	2,231 adults	Cross-sectional dietary	Dinner as largest meal vs.	BMI and metabolic	Dinner-dominant eaters had higher BMI and worse	Shows late timing of main

Study	Population & N	Study Design	Definition of Late Eating / Exposure	Outcomes Measured	Key Findings	Relevance
		timing analysis	breakfast as largest	health indices	cardiometabolic markers.	caloric load correlates with metabolic syndrome markers.

Our small cross-sectional survey aligns directionally with these broader findings. Late eaters exhibited higher rates of overweight and metabolic conditions compared with early eaters, and most late-night meals (85%) were calorie-dense, high-fat, or sugary, which may exacerbate the adverse metabolic effects of circadian misalignment. This interaction between meal timing and diet quality is consistent with prior research indicating that timing may magnify the impact of dietary composition on BMI and cardiometabolic risk (Bandín et al., 2015; Garaulet & Gómez-Abellán, 2014; McHill et al., 2017).

Several limitations warrant acknowledgment. First, the use of self-reported data introduces potential recall bias, and the cross-sectional design precludes determination of causality. Second, the definition of "late dinner" was based on clock time rather than chronotype-adjusted internal circadian phase, which emerging evidence suggests may more accurately predict metabolic response (McHill et al., 2017; Scheer et al., 2009). Third, lifestyle factors such as physical activity, sleep duration, stress, and overall diet quality were not controlled for, representing potential confounders. Larger, longitudinal, and intervention-based studies are needed to clarify whether shifting dinner to an earlier time can improve metabolic outcomes independent of lifestyle modification.

Despite these limitations, the present findings add to a growing body of literature indicating that late-night eating is a modifiable behavioral risk factor with clinically meaningful metabolic consequences. Incorporating meal timing into public health guidelines and lifestyle counseling—alongside diet quality and caloric intake—may offer an underutilized strategy for improving metabolic health and reducing obesity risk.

4. Conclusions

Late dinner consumption is consistently associated with overweight, elevated body fat, impaired glucose metabolism, and features of metabolic syndrome. This relationship is largely mediated by circadian misalignment, reduced diet-induced thermogenesis, hormonal disruptions (e.g., altered leptin and ghrelin rhythms), and impaired postprandial metabolic responses during the biological night. Evidence from observational cohorts, controlled metabolic trials, interventional weight-loss studies, and mechanistic research demonstrates that eating later in the day - particularly near or after dim-light melatonin onset - adversely affects metabolic health independent of total caloric intake or diet composition.

To complement global literature, this article incorporates findings from a cross-sectional survey conducted among adults aged 28–35 years. In this sample, 70% reported eating late dinners, and among them, 66.7% were overweight and 42.9% reported metabolic disturbances such as high blood pressure, elevated cholesterol, or diabetes. The cross-sectional survey presented in this study reinforces these findings in a sample of young adults, showing that late

dinner habits are associated with higher BMI, increased prevalence of overweight, and greater self-reported metabolic disturbances. Moreover, late eaters frequently consume energy-dense, nutrient-poor meals, which may exacerbate the metabolic consequences of misaligned meal timing. Although limited by sample size, these findings align with the broader evidence indicating that late dinner timing may increase the likelihood of overweight and metabolic syndrome features.

From a public health perspective, encouraging earlier dinner consumption (e.g., before 20:00), consistent meal timing, and balanced, nutrient-rich meals may reduce the risk of obesity and metabolic disorders. Incorporating meal timing into dietary guidance - alongside caloric control, diet quality, and lifestyle interventions - represents a promising strategy to improve metabolic health and prevent chronic disease in young adults and broader populations.

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