Meal Timing, Chronotype, and Diet Quality in Adults

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Abstract: ***Chrononutrition, the study of when food is eaten relative to biological rhythms, has become a significant determinant of diet quality and nutritional status. This review draws on methodologies and findings from major epidemiological and cohort studies to examine how eating frequency, breakfast skipping, late-night eating, and meal irregularity affect diet quality, measured through Healthy Eating Index (HEI) variants, and nutrient adequacy. Regional cohorts carry the same signal for circadian misalignment. Late midpoints, delayed first and last meals, and pronounced eating jet lag are associated with poorer diet quality and a shift toward energy-dense, nutrient-poor foods among adults, where misalignment is sharpest. Behavioural work suggests the mechanism is cognitive rather than emotional or uncontrolled eating. These associations are not equally strong across studies; however, they depend on how diet was assessed, whether by questionnaire or weighed food, and how energy misreporting was handled statistically. The evidence supports incorporating temporal meal patterns and chrono-nutritional behaviour into dietary guidelines, both to protect metabolic health and to prevent chronic nutrient inadequacy.***

Keywords: chrono-nutrition; chronotype; meal timing; diet quality; circadian misalignment; adults

1. Introduction

Over the last ten years, the global epidemic of obesity has worsened significantly, resulting in a very serious public health problem. For decades, mainstream metabolic and nutritional science focused on the quantity and composition of food, attributing weight gain solely to calorie surplus; emerging research in chrononutrition reveals a crucial new dimension: the timing of food intake [1]. The field has established that when we eat is just as vital as what we eat, affecting our food choices, how our bodies process energy, our weight, and overall cardiometabolic health [1].

Chrononutrition refers to the timing, frequency and periodicity of eating behaviours. These timing characteristics are connected to the human body's circadian clock system, which is organised hierarchically[1]. The suprachiasmatic nucleus (SCN), a pacemaker in the hypothalamus, is dominant in the system. It orchestrates peripheral oscillators that are present in almost every cell, including those from the liver, pancreas, gut, muscles, and white adipose tissue. Environmental light helps to synchronise the internal biological clock with the SCN and the 24–hour light–dark cycle and is the main external synchroniser of the SCN.[2]
Food intake represents the most potent zeitgeber for peripheral circadian clocks and their associated metabolic rhythms. Under physiologically healthy conditions, feeding – fasting and sleep wake cycles remain temporally aligned with the oscillatory activity of the central clock. When meals are consumed at regular, scheduled times, the food-entrainable oscillator (FEO) elicits food anticipatory activity (FAA), characterised by an anticipatory increase in locomotor activity, core body temperature, digestive enzyme secretion, and gastrointestinal motility, which collectively optimise nutrient absorption and metabolic efficiency [1].

Contemporary societal demands, work – life patterns, urbanisation, and shift work, however, commonly promote irregular eating behaviours that are discordant with human evolutionary adaptations [1,4]. Displacement of food intake into the biological rest phase uncouples peripheral oscillators from the central clock of the suprachiasmatic nucleus, producing pronounced circadian misalignment and consequent changes in glucose, lipid, and blood pressure homeostasis [1].

Young adults are among the most vulnerable to irregular eating [3]. Leaving home, starting university, or entering the workforce dismantles whatever mealtime structure existed before, and meals drift later and become less predictable [2]. Some of this drift is biological rather than merely circumstantial: chronotype – an individual's preferred timing of sleep and activity – is shifted towards eveningness in this age group, which pushes both appetite and food intake into the later hours [3]. This review examines how meal timing shapes diet quality and nutrient adequacy in young adults, and how chronotype, urbanisation and composition of individual meals combine to influence metabolic health and cardiometabolic risk.

2. Methodology

This section synthesises the methodological approaches adopted in leading epidemiological and clinical investigations of the relationship between meal timing, diet quality and nutrient intake in adults.

2.1 Literature search and selection

A narrative review was conducted. Literature was searched in PubMed, Scopus, and Google Scholar for articles published between 2019 and 2026 using a combination of terms: " chrononutrition, "meal timing", "chronotype" "diet quality", "breakfast skipping" and "cardiometabolic". Publications were included if they involved adults (≥ 18 years), assessed chronotype or meal timing, and reported diet quality, dietary intake or cardiometabolic outcomes. Eight publications- two reviews [1,3] and six observational studies [2,4-8] were selected for synthesis.

2.2 Assessment approaches used in the included study

Circadian preferences are usually assessed using validated questionnaires, which classify people as morning(M-type), intermediate (I-type), or evening (E-type) chronotypes [3]. The Horne-Östberg Morningness – Eveningness Questionnaire (MEQ) and its validated shortened version (rMEQ) are the main clinical standards for psychobiological and behavioural preferences [3,4]. A commonly used tool is the Munich Chronotype Questionnaire (MCTQ). It elicits detailed sleep-wake measures on work and work-free days. This quantifies social jetlag, which is the difference in mid-sleep between work and free days [1]. The reference standard for measuring central circadian phase is dim-light melatonin onset (DLMO) from salivary or blood samples to measure actual physiological timing. However, its laborious nature makes the implementation of DLMO in large epidemiological cohorts unfeasible. Based on self-reported sleep diaries, the midpoint of sleep on free days (MSF) derived from self-reported sleep diaries is a powerful proxy to measure chronotype in some studies [1].

2.3 Extraction of chrononutrition and Meal timing variables:

To measure meal timing and regularity, various metrics are carefully extracted.

1) The clock time of first and last eating occasions, defined as the consumption of any food and drink that can provide some energy with food content [2].
2) The calorie midpoint refers to the exact time of the day when 50% of energy intake is consumed [2].
3) The eating window is the time between the start time of the first eating occasion and the last eating occasion on the same day [2].
4) Latency metrics refer to the duration between waking up and the first eating occasion (morning latency), as well as between the last eating occasion and sleeping (evening latency) [2].
5) The day–to–day variability was calculated using the SD of the first /last eating occasion and calorie midpoint; the CV was calculated for eating window and for daily number of eating occasions. The high variability in these measurements from day to day indicates disorganised eating behaviour [2].
6) Meal Irregularity Energy Scores were calculated as the average of absolute differences between energy intake for each meal and the mean energy intake for the past 3 days [5].

2.3 Assessment of diet and diet quality measures

The evaluation of dietary intake and nutrient adequacy occurs through the examination of 24-hour dietary recalls, multi-day food records, or diaries, and food frequency questionnaires (FFQs). Modern technology-based dietary assessment tools include automated wearable cameras, which use Autographer lanyards to capture first-person perspective images every 30 seconds [2]. Moreover, they help reduce recall bias in dietary assessments, which reveal unreported foods as well as provide objective timestamp data on eating occasions [2].

Measures that assess overall diet quality are validated and designed to be used within specific populations. The HEIFA-2013 yields a score reflecting adherence to national dietary guidelines based on 11 components, which are divided into either core or non–core. The combined maximum possible score is 100. The components are the five core food groups; discretionary foods; key nutrients (saturated fat, sodium, sugar and alcohol); and water intake. Several other indices exist, such as the Baltic Sea dietary pattern score [2].

2.5 Statistical modelling and mediation analysis

1) **Linear and Logistic regression:** The study used linear and logistic regression models to investigate direct associations between chrononutritional variables and diet quality scores, adjusting for potential confounders like age, sex, body mass index (BMI), physical activity, and socioeconomic status [2-5].
2) **Structural Equation Modeling (SEM):** This is used to simultaneously examine the direct and indirect relations within one system. For example, treating obesity as a latent variable (indicated by observed BMI and waist circumference) to test its mediating role in the association of meal-specific dietary patterns and cardiometabolic risk factors [5].

3. Results and Discussion

Table I summarises the research settings, specifics and core nutritional findings of included publications

Table I: Summary of key chrononutrition cohort studies and Findings

Reference	Cohort & Study Design	Core chrononutrition focus	Main Findings
[1]	Narrative epidemiological review across life course; circadian mechanisms and cardiometabolic health	Clock pacemakers (SCN), central/peripheral synchronisation, social jetlag, and risk of type 2 diabetes/ CVD	Food acts as a potent peripheral zeitgeber. Ingestion of food during the biological rest phase desynchronizes the peripheral clock from the central SCN clock, causing glucose intolerance, visceral adiposity, adipose tissue inflammation, and arterial hypertension.
[2]	95 young adults (54 university,41 community) in Australia; cross-sectional wearable camera & food record design	Eating window, calorie midpoint, day-to-day eating timing variability and evening eating (at/after 20:00h)	No direct link between eating variability and overall diet quality, but evening eating outcomes depend on health consciousness. University sample had higher diet quality (HEIFA 62.9 vs 44.3) and healthier dinner/fruit evening choices, while the community sample chose discretionary foods
[3]	Scoping review of 36 articles (477,493	Association between chronotype, meal timing	Eveningness is strongly associated with breakfast skipping (up to 60%), late-night eating, binge eating, emotional eating, low

	participants globally); comprehensive mapping of chronotype and diet	(breakfast, lunch, dinner) and nutrient/ food group selection	vegetable intake, and elevated sugar, sweet, fat, caffeine and alcohol consumption. Eveningness leads to weight loss success
[4]	151 adults (75 urban, 76 rural) in Delhi-National Capital Region, India; cross-sectional analytical study	Rural- Urban disparities in chronotype(rMEQ), sleeping and eating window misalignment, sedentary behaviour, and obesity	Urban Participants had significantly higher BMI (25.5 vs 23.2), higher waist circumference, and higher sedentary time (8.8 vs 5.9 h). 57.9% of the rural cohort showed a morning chronotype (vs 10% urban), with less sleep/eating window misalignment
[5]	825 Iranian adults, cross-sectional with structural equation modelling (SEM)	Meal -specific dietary patterns Obesity fully (DPs) at breakfast, lunch, and dinner; meal frequency; and irregularity scores	Obesity mediated the link between lunch and irregularity as well as lipids and blood pressure. Unhealthy oil, eggs, and cereal consumed at breakfast directly increased lipid levels. Dinner high in legumes lowered blood pressure
[6]	Observational cohort study	Chronotype, dietary intake, meal timing, body composition, and metabolic biomarkers	Evening preference correlates with delayed meal timing, altered macronutrient selection, higher body fat percentage, and adverse metabolic biomarker profiles
[7]	Adult cohort across BMI categories	Chronotype, eating behaviour, and circadian preference across mass index categories	Circadian preference significantly influences eating behaviour patterns; evening chronotypes exhibit higher cognitive restraint deficits and irregular eating across normal, overweight, and obese BMI categories
[8]	Urban Kolkata observational study	Chronotype, body mass index, and self- regulatory eating behaviour	Identifies strong links between evening chronotype, elevated BMI, and reduced self-regulatory eating behaviour, highlighting socio-urban environmental triggers of eating misalignment

3.1 Chronotype as Driver of Eating Behaviour and Dietary Intake

Across studies, Women with an evening chronotype show a delayed daily nutrient energy distribution, consuming significantly less energy and macronutrients before 10:00 h and more after 20:00 h [6]. This periodic eating rhythm has been linked to increased body fat percentage, an android-to-gynoid fat ratio, and worse metabolic markers, including higher fasting insulin, HbA1c, triglycerides, and leptin [6]. Food schedules were linked to psychological profiles, showing that circadian preferences are primarily associated with cognitive regulation of appetite rather than emotional motives. In particular, morning chronotypes show significantly greater cognitive restraint, that is, intention and effort to reduce food intake to control weight, particularly among normal-weight individuals and women, whereas emotional eating and uncontrolled eating scores do not differ across chronotypes [7]. An innovative study assessed a cohort in urban Kolkata, India, and found that while chronotype and BMI did not have positive significant associations in the sample, individuals of intermediate chronotype showed significantly greater odds of self-regulation of eating behaviour (SREB) than the evening types (with an odds ratio of 7.77), with the former exhibiting the weakest SREB [8].

In conclusion, the systematic circadian misalignment caused by the internal conflict between natural evenness and social time schedules alters the function of clock proteins and modifies the secretion of metabolic hormones, such as melatonin, leptin and adiponectin [1]. Through this desynchronization, metabolic regulation would be impaired, causing late-functioners to be prone to excess body weight and chronic complications such as hypertension, type 2 diabetes and obstructive sleep apnea [1,3]

3.2 Meal- specific Dietary Patterns and Nutrient Adequacy

The recent investigation indicates that the composition of meals and snacks, rather than solely total calorie intake, significantly influences cardiometabolic health and nutrient adequacy. A structural equation modeling (SEM) framework was employed to analyse data from 825 Iranian adults, identifying specific dietary patterns (DPs) associated with metabolic risk factors. These associations were found to operate either directly or indirectly through obesity as a mediator [5].

1) **Breakfast Dietary Pattern:** A breakfast dietary pattern characterised by high consumption of oil, eggs, and cereals demonstrated a direct correlation with elevated serum lipid levels, specifically higher triglycerides (TG), and an unfavorable ratio of total cholesterol to HDL cholesterol (TC: HDL -C) and LDL cholesterol to HDL cholesterol (LDL – C; HDL- C). Conversely, a suboptimal breakfast composition, including the omission of breakfast, was linked to reduced physical activity levels and an increased body mass index (BMI) [5].
2) **Lunch Dietary Pattern:** The consumption of a lunch dietary pattern comprising oil, potato, dairy and eggs was directly linked with obesity. This particular lunch pattern was indirectly linked to adverse lipid profiles (e.g., HOMA-IR and triglyceride-glucose (TyG) index), with obesity acting as a mediating factor. Furthermore, high scores for lunch energy irregularity were associated with poorer lipid profiles and higher BP, with obesity fully mediating these associations [5].
3) **Dinner Dietary Patterns:** In contrast, a salutary dinner DP, involving the consumption of cereals, oils, poultry, and legumes, was associated with reduced systolic and diastolic blood pressure. The high legume content in certain dietary patterns may promote vasodilation and enhance vascular integrity, potentially due to their rich L–arginine and phenolic content. Conversely, atypical

energy intake at dinner was positively correlated with an unfavorable lipid profile [5].

4) **Frequency of Eating:** Across various models examined, a greater frequency of eating occasions per day was observed to be associated with an improved lipid profile, as evidenced by lower triglyceride and total cholesterol levels. It is hypothesised that consuming meals more frequently but in smaller portions may attenuate serum cholesterol by suppressing insulin secretion, which subsequently down-regulates hepatic cholesterol synthesis and augments low-density lipoprotein (LDL) receptor activity [5].

3.3 Impact of Evening Eating and Social Context on Diet Quality

Meal timing is highly sensitive to an individual's social and interest context. Young adults frequently eat late meals (after 8:00 PM) when their physiological self–control is weaker and cravings for energy–dense, nutrient–poor foods are stronger [2]. This is also influenced by their tendency toward a late chronotype and insufficient sleep [3].

The impact of eating later at night on nutrition is significantly influenced by an individual's awareness of their health and their understanding of nutritional content [2]. In a comparison between university students and a general community sample, students demonstrated substantially higher overall diet quality, as indicated by a Healthy Eating Index for the Australian Diet (HEIFA) score of 59.1 compared to the community sample's 47.3[2]. Interestingly, university students who ate after 8:00 PM exhibited superior diet quality and a higher discretionary food score than their counterparts in the community sample (diet quality: 62.9 vs 44.3; discretionary score: 7.9 out of 10 vs 1.6 out of 10) [2]

The two groups of consumers differed substantially in the food they chose. University students who ate in the evening mostly had healthy dinners (rich in five core food groups) and fresh fruit. On the other hand, evening eaters from the community mostly selected discretionary foods high in saturated fat, added sugar, sodium and alcohol [2]. The results suggest that meal timing per se may be less harmful among high-quality habitual dieters who can exhibit a learned resistance to night-time cravings for discretionary foods due to their nutrition knowledge [2].

3.4 Environmental Discrepancies Between Urban and Rural Areas

The environmental and physical contexts considerably influence chrononutrition profiles and circadian alignment. A detailed comparison between urban and rural adults in the Delhi- National Capital Region, India, revealed significant inequalities in obesity indicators and physical activity, and sizable differences in chronotype and eating window misalignment. City dwellers had significantly higher average body mass index (BMI) (25.5 vs 23.2 kg/m^2) and waist circumference (33.6 vs 27.1 inches) as compared to rural respondents, with 56% of urban participants being obese. This increase in body fat was attributed to lower physical activity levels and significantly higher sitting time (8.8 hours in urban vs 5.9 hours in rural). Rural individuals appear to be strongly morning–oriented, with 57.9%of rural participants reporting a definitely morning chronotype, compared to only 10% of urban individuals. Consequently, urban participants displayed notable misalignment between their preferred and actual sleeping and eating windows, with meals often occurring much later than preferred. For example, participants experienced an actual evening eating latency of 2.3 hours, falling short of the preferred 1.9 hours, and frequently ate meals and snacks after dinner. In contrast, the rural group had a longer eating window (13.4 hours compared to 12.0 hours); their sleep and eating times were much more synchronised. Evidence suggests that the social and cultural pressures of urban life, including commute times, work demands, and exposure to artificial light, disrupt the body's natural biological rhythms. This disruption, in turn, leads to greater misalignment between eating and sleeping patterns, elevating the risk of obesity [4].

3.5 Physiological Mechanisms: Circadian Misalignment and Cardiometabolic Risk

Complex physiological and endocrine mechanisms mediate the harmful metabolic impact of meals taken late and an irregular eating pattern. The act of changing feeding activity to the biological rest phase (late evening or night eating) causes a primary desynchronisation of the central master clock in the suprachiasmatic nucleus (SCN) from the peripheral clock tissues [1]. Nutrient consumption during the rest phase disrupts the resting energy requirement (RER) rhythm and stimulates de novo lipogenesis, which promotes fat deposition and visceral adiposity [1]. Central obesity is characterised by chronic low-grade inflammation, involving the infiltration of immune cells into adipose tissues and the hypersecretion of pro- inflammatory cytokines. This inflammation of fat tissue ultimately results in insulin resistance and vascular dysfunction [1]. Animal studies show that even brief periods of feeding during the rest phase can lead to significant leptin resistance and elevated HbA1c levels [1]. This progression of diabetes is indicated by clinical markers such as increased Homeostatic Model Assessment of Insulin Resistance (HOMA–IR) and elevated Triglyceride – Glucose (TyG) index, both of which are strong predictors of type 2 diabetes and cardiovascular diseases [1,5].

4. Conclusion

The timing of meals strongly influences the quality of dietary nutrient intake and long-term metabolic health. The food we consume is regulated by the interaction between our internal biological clocks and the appropriate type of macronutrient consumption in the food. youn Adults who are night owls may struggle to eat regularly. They eat late, often skipping breakfast and preferring more calorie–dense foods in the evening, which can offset their skipped meals. Sleeping with the bright lights switched on, staying up late, and eating a heavy meal at night interrupt the biological clock, which can lead to inflamed fat tissue. Nonetheless, these risks raise the likelihood of developing leptin resistance and also insulin resistance, which increase the risk of obesity and type 2 diabetes. A solid understanding of nutrition can prevent unhealthy late- night eating by helping with eating behaviours. Public health initiatives to manage obesity and cardiometabolic disease involve reducing urban stress, minimising the misalignment of the timing of meals and personalising dietary modulation based on a person's chronotype.

5. Further Directions

Advancing chrononutrition research requires addressing several key methodological gaps [1-3]. Cross-sectional protocols should be replaced with prospective cohort studies to establish the causal and temporal relationships between chronotype, meal timing, and the onset of cardiometabolic disease [2-5]. Psychometric instruments such as the Morningness-Eveningness questionnaire (MEQ) and Munich chronotype questionnaire (MCTQ) should be complemented with objective physiological phase markers, including dim-light melatonin onset (DLMO), continuous actigraphy, based on self-reported sleep diaries, the midpoint of sleep on free days (MSF) acts as a powerful proxy and metabolomic and transcriptomic profiling [1]. Passive wearable cameras, real-time photographic food logs, and automated barcode scanning should be used to reduce recall bias and ensure accurate time-stamping of dietary intake [2]. Dietary interventions should be tailored to individual chronotypes and shift-work schedules.

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