ABSTRACT
Current literature has accumulated evidence on the effect of circadian cycle dysregulation on metabolic disorders and obesity. Several factors can cause chronodisruption; however, increasing attention has been given to the temporal pattern of meals. Objective: To review the evidence on the relationship between skipping breakfast and late eating and obesity and metabolic disorders. Methods: This narrative review whose searches were conducted in August 2022 in the electronic databases of the National Library of Medicine (PubMed) and the Virtual Health Library (VHL). Inclusion criteria were: (1) original articles; (2) published in English and/or Portuguese; (3) keywords in the title, abstract, or subject; and (4) published in the last 20 years (2002-2022). The exclusion criteria were: (1) review articles; (2) not available in full; (3) off-topic; and (4) studies with children and/or adolescents. Results: Thirteen articles met the inclusion criteria. In both cohort and cross-sectional studies, as well as in randomized clinical trials, an unfavorable association was observed between skipping breakfast and late eating and metabolic disturbances and obesity. Conclusion: Evidence to date shows that mealtime has a significant influence on energy metabolism and metabolic disorders. The application of chrononutritional knowledge can be an important tool for the prevention and control of metabolic diseases associated with overweight and obesity.

Keywords: chrononutrition, circadian cycle, biological clock, metabolic disorders.
RESUMO
A literatura atual acumulou evidências sobre o efeito da desregulação do ciclo circadiano em distúrbios metabólicos e obesidade. Vários fatores podem causar cronodisrupção; entretanto, atenção crescente tem sido dada ao padrão temporal das refeições. Objetivo: Revisar as evidências sobre a relação entre pular o café da manhã e comer tarde e obesidade e distúrbios metabólicos. Métodos: Trata-se de uma revisão narrativa cujas buscas foram realizadas em agosto de 2022 nas bases de dados eletrônicas da National Library of Medicine (PubMed) e da Virtual Health Library (BVS). Os critérios de inclusão foram: (1) artigos originais; (2) publicado em inglês e/ou português; (3) palavras-chave no título, resumo ou assunto; e (4) publicados nos últimos 20 anos (2002-2022). Os critérios de exclusão foram: (1) artigos de revisão; (2) não disponível na íntegra; (3) off-topic; e (4) estudos com crianças e/ou adolescentes. Resultados: Treze artigos atenderam aos critérios de inclusão. Tanto em estudos de coorte quanto em estudos transversais, bem como em ensaios clínicos randomizados, foi observada uma associação desfavorável entre pular o café da manhã e comer tarde e distúrbios metabólicos e obesidade. Conclusão: As evidências até o momento mostram que o horário das refeições tem uma influência significativa no metabolismo energético e nos distúrbios metabólicos. A aplicação do conhecimento crononutricional pode ser uma ferramenta importante para a prevenção e controle de doenças metabólicas associadas ao sobrepeso e à obesidade.

Palavras-chave: crononutrição, ciclo circadiano, relógio biológico, distúrbios metabólicos.

1 INTRODUCTION
Traditionally, research linking nutrition with cardiometabolic disorders has focused on the nutritional value of the diet. However, the importance of meal timing in overall health is increasingly recognized. Not just what or how much you eat, but when you eat, plays a central role in regulating body weight and metabolism. Chrononutrition is an emerging field of research that relates the timing of food intake to the circadian rhythm, studying the effect of food at certain times of the day on an individual's health status. The circadian rhythm is the oscillation of endogenous metabolism that occurs in a cycle of approximately 24 h. It coordinates the rhythm of endocrine and metabolic pathways necessary for homeostasis. Thus, food intake in coordination with the body's daily rhythms, in addition to food quantity and quality, can be a critical tool for preventing obesity and cardiometabolic disorders. It is important to consider not only the nutritional value but also the timing of food consumption.

In modern society, many individuals often work, eat, and sleep in disagreement with their biological clock. The literature points to changes in the temporal patterns of eating in the population, with a growing tendency to skip meals, especially breakfast. However, this behavior alone is considered a risk factor for overweight and metabolic diseases due to chronic desynchronization of the circadian cycle. A meta-analysis reviewing the results of 9 cohorts found that skipping breakfast increased the risk of overweight/obesity by 44% compared to eating breakfast, with no significant difference between age, sex, and economic status. Additionally, eating during a biologically programmed sleep period appears to favor weight gain and impair metabolic health.
Considering the growing prevalence of overweight and obesity worldwide, there is growing interest in strategies that can contribute to the control and prevention of this public health problem. Based on this context and the repercussions of circadian cycle desynchronization on human health, the present review aims to examine the evidence on the relationship between skipping breakfast and late eating with obesity and metabolic disorders.

2 METHODS

Searches for this narrative review were conducted in August 2022 in the electronic databases of the National Library of Medicine (PubMed) and the virtual health library (VHL). The descriptors used were circadian rhythm, eating behaviors, and obesity. The search criteria were as follows: (1) descriptors in the title, abstract, or subject; (2) in article form; and (3) full version available.

Studies were evaluated according to the following inclusion criteria: (1) original articles; (2) published in English and/or Portuguese; (3) keywords in the title, abstract, or subject; and (4) published in the last 20 years (2002-2022). The exclusion criteria were: (1) review articles, (2) not available in full, (3) off-topic, and (4) studies with children and/or adolescents.

The first round of selection was conducted by reading the titles of the papers that were related to mealtimes and obesity and/or cardiometabolic disorders. Then, the abstracts were analyzed, and those that met the selection criteria were read in full. Information on author and year, objective of study, methods, and results were collected for later analysis.

3 RESULTS AND DISCUSSION

Searches resulted in 538 articles from PubMed and 376 from VHL. After applying the inclusion and exclusion criteria, 13 studies involving 103,805 adults of both sexes were selected. The analyzed articles had common objectives, including investigating the relationship between temporal eating patterns, metabolic disorders, and obesity. However, a higher number of studies investigated only the effect of skipping breakfast. Of the selected studies, seven had a cross-sectional design, three were cohort studies, two were randomized clinical trials, and one was a quasi-experimental study. Table 1 summarizes the main information of the selected articles.

For the presentation of the results and discussion they were categorized into relationships of obesity and metabolic disorders with (1) skipping breakfast; (2) late eating.
3.1 RELATIONSHIP BETWEEN SKIPPING BREAKFAST AND OBESITY AND METABOLIC DISORDERS

The reviewed studies provided evidence that skipping breakfast is associated with weight gain and cardiometabolic risk factors, which appear to be related to circadian cycle disruption.

Deshmukh-Taskar et al. (2013), in a cross-sectional study with 5,316 North American adults, observed that almost a quarter of the participants (young adult population: 20–39 years old) skipped breakfast. They further identified that eating breakfast was associated with a lower prevalence of overweight/obesity, abdominal obesity, and several other cardiometabolic risk factors, in contrast to the potential adverse metabolic effects observed in those who skipped breakfast.

Mirghani (2021) investigated the cross-sectional association between skipping breakfast and late eating with body mass index (BMI) and glycemic control of 310 patients with type 2 diabetes mellitus (T2DM). He observed that skipping breakfast and consuming dinner at later times was associated with overweight and poor glycemic control.

Watanabe et al (2014) observed that skipping breakfast was significantly related to increased waist circumference and BMI. The authors concluded that skipping breakfast appears to be more closely associated with obesity indicators than eating late.

The mechanisms underlying skipping breakfast and an increased risk of metabolic disorders and obesity are not fully understood; however, some aspects may explain these findings. First, skipping breakfast is associated with reduced satiety and increased appetite, which can result in overeating throughout the day. One explanation is that a longer fasting period may result in a greater release of ghrelin, a peptide hormone related to increased appetite. In contrast, eating breakfast is associated with lower concentrations of postprandial ghrelin, which reduces appetite throughout the day.

In addition, skipping breakfast can reduce glucose tolerance and impair insulin sensitivity. Skipping breakfast appears to alter the expression of genes involved in the circadian cycle and metabolism, compromising hormone secretion, and increasing postprandial blood glucose levels. For example, a cross-sectional study of 52 non-diabetic adults found that eating breakfast was significantly associated with increased insulin sensitivity. Additionally, a randomized clinical trial with 18 individuals with T2DM and 18 healthy individuals revealed that consuming breakfast can increase serum glucose levels and insulin sensitivity at subsequent meals. Thus, skipping breakfast appears to acutely disrupt circadian rhythms in both healthy individuals and those with metabolic disorders such as T2DM.

Finally, it should be considered that regular consumption of breakfast is associated with healthier food choices and the practice of regular physical activity, lifestyle habits that are beneficial for metabolic health and maintenance of a healthy weight.
3.2 RELATIONSHIP BETWEEN LATE EATING WITH OBESITY AND METABOLIC DISORDERS

The literature has also identified that late meals are associated with a greater likelihood of overweight and cardiometabolic disorders.

Dashti et al. (2020) studied a cohort of 3,362 overweight and obese Spanish adults to investigate whether eating late was associated with obesity, cardiometabolic risk factors, and the rate of weight loss. The authors observed that having meals later at night was associated with higher BMI and obesogenic behaviors such as eating when stressed, overeating at night, and while watching TV. In addition, when compared to individuals who ate early in the evening, individuals who ate late had higher concentrations of triglycerides, lower insulin sensitivity, a lower percentage of weight loss, higher concentrations of leptin and fasting insulin by morning, more barriers, and less motivation to lose weight.

In a cross-sectional study with 110 adult participants, McHill et al. (2021) examined the relationship between the timing of food consumption, meal content, and body composition. Individuals who consumed a higher percentage of their daily calories within 4 h before the onset of sleep at night had a higher percentage of body fat. Thus, the authors concluded that evening food consumption, regardless of more traditional risk factors, such as the amount or content of food intake and level of physical activity, plays an important role in body composition.

Shim et al. (2021) analyzed cross-sectional data from 13,361 Korean adults and observed that late food consumption was significantly associated with higher BMI, higher caloric intake, higher blood triglyceride concentration, and a nutritionally poorer food profile. McHill et al. (2017), Mirghani (2021), and Kahleova et al. (2017) also identified an association between that late meal intake and a greater likelihood of overweight and increased body fat.

A cross-sectional study of 19,687 adult and elderly Japanese women found that 11% of the participants tended to have late dinners, 22% to have bedtime snacks, and 8% to skip breakfast. All three eating behaviors were significantly associated with a higher prevalence of overweight. Furthermore, the combination of eating later in the evening (late dinner and/or bedtime snacks) and skipping breakfast is strongly associated with a higher prevalence of overweight/obesity.

One of the justifications for avoiding late food consumption is the role of melatonin. The increase in melatonin levels occurs within 2–3 h before the onset of usual sleep. Simultaneous increases in melatonin and serum glucose levels appear to impair glucose tolerance because melatonin inhibits glucose-stimulated insulin secretion.

Some studies also suggest that the relationship between obesity and metabolic disorders and night eating can be explained by a greater preference for more fatty foods at dinner than at breakfast. For example, Shim et al. (2021) observed that participants who eat meals later in the evening had a food profile that was poorer in micronutrients and richer in fat than those who had meals earlier.
Another potential mechanism is a decrease in the thermic effect of food at night. In the randomized clinical trial conducted by Bandin et al. (2014), it was observed that a delay in the timing of a meal caused a decrease in the thermic effect of food, in addition to a reduction in resting energy expenditure, fasting carbohydrate oxidation, and glucose tolerance. These factors can contribute to a positive energy balance and consequent weight gain.

More recent studies have investigated the association between overweight/obesity and the temporal pattern of energy intake (individual chronotype). The nocturnal chronotype had higher food consumption at night than the morning chronotype. In a recent study, Mazri et al. (2022) explored the association between mealtimes according to chronotype (morning and afternoon). For this, they developed a 12-week weight loss program. Individuals were categorized into two groups according to chronotype, which was assessed using the Munich Chronotype Questionnaire. Subjects with a morning chronotype consumed 75% of their total calories in the morning (30% at breakfast, 10% at a morning snack, and 35% at lunch), and only 25% at night. Those with the nocturnal chronotype consumed 60% of total calories in the morning (20% at breakfast, 5% at a morning snack, and 35% at lunch) and 30% of calories at dinner. The remaining percentage comprised afternoon snacks.

Thus, in both chronotypes, most calorie intake occurred in the morning. After the intervention, both chronotypes significantly reduced the total caloric intake (mean difference: -471 kcal) and macronutrient intake. The participants lost 4.8% of the initial weight (−4.0 ± 4.4 kg/m2) and had a significant reduction in all adiposity parameters after the 12 weeks of intervention. The morning chronotypes lost 5.3% of their weight in relation to their baseline weight, with a BMI reduction of -1.7 kg/m2, -2.2% body fat, and -3.6 cm in waist circumference. The nocturnal chronotypes lost 4.3% of their body weight, with a BMI reduction of -1.4 kg/m2, -1.8% body fat, and -4.1 cm in waist circumference. However, no significant differences were observed between the two groups in any adiposity parameter. Both chronotypes had a significant reduction in homeostasis model assessment-estimated insulin resistance, triglycerides, and blood pressure.

The morning and afternoon chronotypes had their last meals earlier compared with pre-intervention and also maintained a 2.5h interval between the last meal and the onset of sleep. The authors concluded that, regardless of chronotype, a higher energy intake at the beginning of the day and a lower intake at the end of the day is beneficial for metabolic health and the maintenance of adequate weight. Thus, the combination of a low-calorie diet, physical activity, and appropriate mealtimes is beneficial for weight reduction in both chronotypes.

3.3 MAIN RECOMMENDATIONS

The main recommendations based on the results of the reviewed studies are summarized in Figure 2. In general, the recommendations consist of not skipping breakfast, consuming most calories in the
morning (65-70% of total calories), lunch with a 5-6 hour break after breakfast, consuming the main meal before 3 pm, reducing food intake during the evening, and eating dinner at least 2 ½ hours before bedtime. Benefits include a higher chance of weight loss success; better weight control; lower body adiposity; healthier food choices; better glycemic control (greater sensitivity to insulin), appetite, and blood pressure; better oxidation of nutrients; and reduction of triglyceride levels.

Thus, the results obtained in this review reinforce the use of the practical application of chrononutrition knowledge to contribute to the prevention and control of overweight/obesity and metabolic disorders.

4 FINAL CONSIDERATIONS

The most recent evidence suggests that mealtime has a significant influence on the biological clock and consequently on metabolic disorders. Overall, the results of this review suggest that eating breakfast is associated with increased satiety, better insulin sensitivity, and glucose tolerance at subsequent meals. However, eating meals at night often has the opposite effect, increasing the risk of metabolic disorders and obesity. However, more prospective studies and clinical trials are recommended, given that most of the studies reviewed in the present investigation were cross-sectional, making it impossible to infer a causal relationship.

The practical message of this study is that the timing of meals should be considered, for example, not skipping breakfast and avoiding late meals, to prevent overweight/obesity and metabolic disorders. The application of chrononutrition knowledge can be an instrument for behavioral changes, contributing to weight loss and appetite modulation through food quantity and composition, together with eating at the most favorable time of day. However, more randomized controlled trials based on chrononutritional knowledge are needed.

From the results of this review, chrononutrition should be considered in practice because, even with its research basis still in development, the available findings highlight its relevance for individual metabolic health.
REFERENCES


KAHLEOVA, Hana et al. Meal frequency and timing are associated with changes in body mass index in Adventist Health Study 2. *The Journal of nutrition*, v. 147, n. 9, p. 1722-1728, 2017.


ANNEXES

Figure 1. Flowchart of the research strategy and selection of studies.

**Descriptors**
- circadian rhythm;
- feeding behavior;
- obesity

**Inclusion criteria:**
1. original articles
2. published in English and/or Portuguese
3. keywords in the title, abstract, or subject
4. published in the last 20 years (2002-2022)

**Total:** 13

Figure 2. Summary of the main recommendations of the reviewed studies on the temporal pattern of meals, and associated cardiometabolic benefits.

- Reduce food intake at night
- Dinner should be eaten at least 2 h before bedtime
- Don’t skip breakfast
- Consume most calories in the morning (40-70% of total kcal)
- Have lunch 5 to 6 hours apart after breakfast
- The main meal of the day must be consumed by 3 pm

**Main benefits**
- More chance of weight loss success
- Better weight control
- Lower body adiposity
- Healthier food choices
- Better appetite control
- Better glycemic control
- Better oxidation of nutrients
- Blood pressure control
- Decreased serum triglycerides
Table 1. Characteristics of studies selected for reviewing the most recent evidence on the relationship between skipping breakfast and late eating with obesity and metabolic disorders.

<table>
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<th>Reference</th>
<th>Objective</th>
<th>Method</th>
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| Bandín et al., 2014| To investigate the effects of mealtime changes on energy expenditure, glucose tolerance, and circadian-related variables. | **Type of study:** Randomized Control Case  
**Population:** 32 women aged 24 ± 4 years  
**Study location:** Spain (Murcia)  
**Methods:** Women were included in two protocols:  
- Early Eating (EE) - Protocol 1  
- Late Eating (LE) – Protocol 2  
(1) Ten women were enrolled in protocol 1: age, 26 ± 4 years; BMI 22.54 ± 2.05 kg m²; body fat percentage 27.07 ± 6.10.  
(2) 22 women participated in protocol 2: age, 24 ± 4 years; BMI 23.19 ± 2.99 kg m²; body fat percentage 25.61 ± 6.25. | - Delaying a meal during a week resulted in decreased resting energy expenditure, decreased fasting carbohydrate oxidation, decreased glucose tolerance, and decreased thermic effect of food. |
| Dashti et al., 2020 | To determine whether late feeding is transversally associated with obesity and cardiometabolic risk factors and to identify obesogenic behaviors and barriers to weight loss associated with late feeding. | **Type of study:** Cohort  
**Population:** 3,362 overweight or obese adults  
**Study location:** Spain  
**Inclusion criteria:** voluntary participation, subject to written informed consent.  
**Exclusion criteria:** individuals who were receiving treatment with thermogenic or lysogenic drugs; with anxiolytics or antidepressants; or have diabetes mellitus, chronic kidney failure, liver disease or a diagnosis of cancer, bulimia or prone to binge eating.  
**Methods:** Participants attended 1 weekly 60-minute small support group therapy session for 5 months. The program was led by certified nutritionists and was based on the Mediterranean diet. Dietary energy was limited to 1200 to 1800 kcal per day for women and 1500 to 2000 kcal per day for men to induce an approximate loss of 0.5 to 1 kg per week in order to achieve a total weight loss of 5 to 10% of the initial weight. The midpoint mealtime was calculated, and subjects were divided into early and late eaters. | - Late eaters had higher concentrations of triglycerides and lower insulin sensitivity compared to early eaters;  
- Weight loss among late eaters compared to early eaters was 17% lower;  
- Late eaters had a significantly higher baseline BMI and were more likely to be obese compared to early eaters.  
- Late eaters had higher concentrations of the satiety hormone leptin in the morning, and higher fasting insulin;  
- Late eaters had an 80 g lower average weekly rate of weight loss, higher odds of having barriers to weight loss, and lower odds of weight loss motivation compared to early eaters. |
| Deshmukh-Taskar et al., 2012 | To examine the association between skipping breakfast with overweight, obesity, abdominal obesity, and metabolic syndrome (MS). | **Type of study:** Cross-sectional  
**Population:** 5316 adults (20-39 y)  
**Study location:** USA | - 23.8% of participants reported skipping breakfast;  
- The mean values of BMI, WC, skinfolds, systolic blood pressure, total serum cholesterol, LDL- |
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<td><strong>Methods:</strong></td>
<td>- Adult members of Seventh-day Adventist churches in the United States and Canada (≥30y) were enrolled and completed the AHS-2 questionnaire “Connecting Lifestyle to Illness and Longevity,” which included medical history, dietary habits, physical activity, and demographic information. Follow-up using the biennial Hospital History</td>
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- Body weight significantly decreased in both BF and D groups over 12 weeks. However, compared to the D group, the BF group showed a 2.5 times greater weight loss.  
- BMI was significantly different between groups, with a 10% reduction in the BF group and only a 5% reduction in the D group.  
- Participants assigned to plan BF also showed a greater reduction in waist circumference than participants assigned to plan D, both at 6 and 12 weeks of follow-up.  
- The results demonstrate that the high-calorie breakfast shows greater adherence and is more beneficial than the high-calorie dinner for weight loss, insulin sensitivity and hunger suppression.  
- Avoiding high-calorie evening meals may be particularly beneficial for improving glucose and lipid profiles and may lead to reduced risk of type 2 diabetes and cardiovascular disease.  
- Individuals who ate 1 or 2 meals/d had a reduction in BMI per year in kg compared to those who ate 3 meals/d.  
- Correspondingly, the BMI of subjects who had a long overnight fast decreased compared to those who had a medium overnight fast (12–17 h).  
- Breakfast eaters experienced a decrease in BMI compared to non-breakfast eaters.  

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Form (HHF) recorded hospitalizations, major health events, and some lifestyle and demographic factors.
- The analysis used data from the number of meals per day, duration of overnight fasting, breakfast consumption and time of the largest meal were the exposure variables.

Mazri et al., 2022

To describe the development of an integrated weight reduction chrononutrition program and the assessment of attendance, retention, satisfaction and adherence to chrononutrition components between the morning and afternoon chronotypes for overweight/obese workers.

**Type of study:** Quasi-experimental study

**Population:** 91 overweight/obese workers (age: 39.6 ± 6.3 years; 74.7% women; BMI: 31.2 ± 4.5 kg/m²)

**Study location:** Malaysia

**Methods:** A 12-week weight loss program (The SLIMSHAPE™ Chrono) carried out in two phases:
1. development of the integrated weight reduction chrononutrition program and
2. evaluation of the integrated program through a feasibility study.

- In terms of total food intake, morning and evening chronotypes significantly reduced total energy (mean difference (MD): -471 kcal and post-intervention macronutrient intake.

- The integrated chrononutrition program for weight reduction between the morning and afternoon chronotypes improved the temporal pattern of energy intake, meal times, night eating syndrome and post-intervention sleep habits.

- After the intervention, both chronotypes significantly reduced total caloric intake (mean difference: -471 kcal) and macronutrient intake.

- The participants lost 4.8% of the initial weight (−4.0 ± 4.4 kg/m²) and had a significant reduction in all adiposity parameters after the 12 weeks of intervention.

- The morning chronotypes lost 5.3% of their weight compared to their baseline weight, with a reduction of -1.7 kg/m² in BMI, -2.2% in body fat and -3.6 cm in waist circumference. The nocturnal chronotypes lost 4.3% of their body weight, with a reduction of -1.4 kg/m² in BMI, -1.8% in body fat and -4.1 cm in waist circumference.
McHill et al., 2017  
To examine the relationships between time of food consumption relative to clock time and endogenous circadian time, food intake content and body composition.  

Type of study: Cross-sectional  
Population: 110 participants (66 women) aged between 18 and 22 years.  
Study location: Canada  
Methods: For 7 consecutive days, participants were asked to log all food and beverages they consumed, with the exception of water, using the MealLogger mobile app (Wellness Foundry). MealLogger allowed participants to take a time-stamped photograph of their meal, include a detailed description of the meal's contents, and identify which meal they were eating (i.e., breakfast, lunch, dinner, drink, or snack).  

- Individuals who consumed a higher percentage of their daily calories before bed had a higher percentage of body fat.  
- Eating at night, regardless of more traditional risk factors such as amount or content of food intake and level of physical activity, plays an important role in body composition.

Mirghani et al., 2021  
To determine the relationship between skipping breakfast and eating late at night with body mass index and glycemic control in patients with type 2 diabetes.  

Type of study: Cross-sectional  
Population: 310 patients with Type 2 diabetes (T2DM)  
Study location: Tabuk City, Saudi Arabia  
Inclusion criteria: All adults with T2DM.  
Exclusion criteria: Adults with type 1 diabetes and pregnant women.  
Methods: A structured questionnaire was used to interview the participants, demographic data, lack of breakfast, late-night eating, smoking, exercise level, family history of diabetes, and complications of diabetes were collected.  
Breakfast was defined as any food or drink consumed between 5:00 and 10:00; dinner defined as two hours before bedtime at least three times a week, and skipping breakfast was defined as skipping breakfast at least three times a week.  

- Skipping breakfast was correlated with BMI;  
- A directly positive correlation was evident between late dinner intake, BMI and HbA1c.

Okada et al., 2019  
To evaluate the association of habitually eating late at night and skipping breakfast with the prevalence of overweight/obesity.  

Type of study: Cross-sectional  
Population: 19,687 Japanese women, aged between 40 and 74 years.  
Study location: Japan  
Methods: Participants were given a self-administered questionnaire about their health. In the questionnaire, three eating behaviors were evaluated: snacking before going to bed, having dinner late and skipping breakfast.  

- In this study, it was observed that the habitual eating behaviors of having a late dinner and having a snack before going to bed were associated with a greater probability of skipping breakfast and also with a higher prevalence of overweight regardless of skipping breakfast.  
- Night eating was more frequent among individuals with obesity than among those without.
and these individuals are more likely to engage in binge eating.
- Both late dinner and bedtime snacking were associated with the prevalence of skipping breakfast. These nighttime eating behaviors, as well as skipping breakfast, were independently associated with a higher prevalence of overweight.
- BMI and waist circumference values were higher for participants who ate dinner less than three hours before bedtime (<3h group) than those who ate more than three hours before bedtime (>3h group).
- Participants who skipped breakfast had higher SBP, DBP, fasting blood glucose, 2-hour post-load blood glucose and triglycerides values than participants who did not skip breakfast.
- Skipping breakfast was also significantly associated with eating late night snacks and having dinner after 8pm.
- Skipping breakfast significantly influenced both waist circumference and BMI.

**Watanabe et al., 2014.** To investigate the relationship between meal times and obesity, based on analyzes of physical measurements, serum biochemical markers, nutrient intake and lifestyle factors in the context of chrononutrition.

**Type of study:** Cohort  
**Population:** 766 participants (480 women) aged between 30 and 79 years.  
**Study location:** Japan  
**Methods:** A questionnaire was applied with information about:  
(1) physical measurements (waist circumference, blood pressure, etc.);  
(2) serum biochemical markers (total cholesterol, etc.);  
(3) a detailed questionnaire on lifestyle factors such as family structure and daily habits (22 questions), exercise and eating habits (28 questions), alcohol consumption and smoking;  
(4) a food frequency questionnaire based on food groups;  
(5) questionnaire about the consumption times of meals and snacks.

**Rangaraj et al., 2020** To examine whether the usual time of energy intake was associated with insulin sensitivity in healthy volunteers.

**Type of study:** Cross-sectional  
**Population:** 52 adult participants  
**Study location:** Chicago (USA)  
**Methods:** Participants were asked to continuously wear a waterproof wrist motion monitor (actigraph) for 10 days, and to complete a 3-day food diary.  
- Within a week of completing the 10-day home session, participants were admitted to the University of Chicago Sleep Research Laboratory and Clinical Research Center in the early evening (between 5:00 pm and 6:30 pm) and began to fast at 8:00 pm, when only water was allowed. Participants had the opportunity to sleep 10 hours from 22:00 to 8:00. A 5 h 12 sample oral glucose tolerance test (5 h OGTT) was performed starting at 9:00 am the following morning.

- Consuming a higher proportion of energy in the morning was significantly associated with greater insulin sensitivity.
- A higher proportion of carbohydrates consumed in the morning was significantly associated with greater insulin sensitivity.
- Meal timing has emerged as an eating behavior with pronounced effects on metabolic health.
Participants completed a self-administered prospective food diary of food and drink consumed over 3 days, which included a combination of weekdays and weekend days to determine usual energy intake.

- The food diary required participants to record the description of the food/beverage, the amount of food consumed, and the time of consumption start. Participants classified each meal as breakfast, lunch, dinner or snack. To provide clarity and ensure consistency, the food diary included detailed instructions on the type of information the participant should record, and these instructions were explained in person before the start of the food recording period and the completed food records were subsequently reviewed.

| Shim et al., 2021 | To investigate whether late feeding is associated with blood pressure control and cardiometabolic risk factors among Korean adults with hypertension. | **Type of study:** Cross-sectional  
**Population:** 13,361 adults with hypertension (6,244 men and 7,117 women)  
**Study location:** Korea  
**Inclusion criteria:** Adults with hypertension aged 30-79 years.  
**Exclusion criteria:** pregnant and lactating women and/or individuals with wrong information about the time of each eating episode.  
**Methods:** Assessed dietary intake and mealtime information using data from the Korea National Health and Nutrition Examination Survey (KNHANES) 2010–2018. Trained nutritionists collected information on intake and dietary habits through 24-hour recall of 1 day.  

The study defined a feeding schedule for early eaters (before 1:45 pm) and late eaters (after 1:45 pm), parameters such as waist circumference, BMI, laboratory tests, among others, were used.

- There were differences in food profiles between early and late eaters, where late eaters had a nutritionally poorer food profile than early eaters, according to the Korean Healthy Eating Index (KHEI), which assesses the quality of an individual’s diet according to the guidelines Dietary guidelines for Koreans.  
- Late eaters had more eating episodes and more energy intake than early eaters, the frequency of main meals were lower, but the frequency of snacks was much higher;  
- Late intake was significantly associated with higher BMI and higher blood triglyceride concentration.

| Song et al., 2005 | To test the hypothesis that breakfast consumption is associated with weight status as measured by body mass index in US adults. | **Type of study:** Cross-sectional  
**Population:** 9,965 adults of both sexes (≥19 y)  
**Study location:** USA  
**Methods:**  

- Consuming breakfast has been shown to be associated with a desirable macronutrient profile to prevent obesity. |
Dietary data were based on respondents’ recall of food consumption during the previous 24-hour period; Participants were recruited and categorized by age, gender and breakfast consumption (consumers and non-consumers).