MLS - HEALTH & NUTRITION RESEARCH

https://www.mlsjournals.com/MLS-Health-Nutrition

Health & Nutrition Research

How to cite this article

Anaya, C. (2023). Relación entre el horario de comidas, la composición corporal y pérdida de peso. MLS *Health & Nutrition Research, 2*(1), 22-35

RELATIONSHIP BETWEEN MEAL TIMING, BODY COMPOSITION AND WEIGHT LOSS

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Summary. Weight gain among the world's population has been a relevant issue in recent years. Nutritional approaches that take into account the timing and frequency of meals may be of interest in improving body composition and weight. The objective is to know if there is a relationship between the number and timing of meals, body composition and weight loss. A bibliographic review was carried out, scientific articles were selected and consulted, both studies and reviews, official websites and relevant documents. A total of 12 studies published in the last 5 years belonging to the Pubmed and Scielo databases were taken into account and analyzed in depth. In addition, the use of the Google search engine was employed for official pages, Both the timing of meals and the frequency at which they are eaten or the macronutrients they ingest are effective dietary-nutritional strategies for body composition and weight modification. More current research is needed, especially in the area of meal frequency to demonstrate effects on body composition, however, it can be concluded that both consideration of macronutrient intake and food timing are possible competent nutritional approach strategies for body composition and weight change.

Key words: Chrononutrition, meal timing, meal frequency, body balance and macronutrients.

RELACIÓN ENTRE EL HORARIO DE COMIDAS, LA COMPOSICIÓN CORPORAL Y PÉRDIDA DE PESO

Resumen. El aumento de peso entre la población mundial es un tema relevante en estos últimos años. Abordajes nutricionales que tengan en cuenta los horarios de las comidas, así como su frecuencia pueden ser interesantes a la hora de mejorar la composición corporal de la población y el peso. El objetivo es conocer si existe relación entre el número y el horario de las comidas, la composición corporal y la pérdida de peso. Se realizó una revisión bibliográfica, fueron seleccionados y consultados artículos científicos, tanto estudios como revisiones, webs oficiales y documentos relevantes. Se tuvieron en cuenta un total de 12 estudios publicados en los últimos 5 años pertenecientes a la base de datos Pubmed y Scielo, los cuales fueron analizados en profundidad. Además, se empleó el uso del buscador de Google para páginas oficiales, Tanto el horario de las comidas como la frecuencia en la que estas se realizan o los macronutrientes que

ingieren son estrategias dietético-nutricionales efectivas para la modificación de la composición corporal y del peso. Se necesitan un mayor número de investigaciones actuales, sobre todo en el ámbito de la frecuencia de las comidas para demostrar los efectos sobre la composición corporal, sin embargo, se puede concluir que tanto tener en cuenta los macronutrientes que se ingieren como el timing alimentario, son posibles estrategias de abordaje nutricional competentes para el cambio de composición y peso corporal.

Palabras clave: Crononutrición, horario de las comidas, frecuencia de las comidas, balance corporal y macronutrientes.

Introduction

The relationship between our internal state and the environment, as well as the way in which the latter affects us was first named by Jean-Jacques d'Ortus de Mairan in the eighteenth century (1,2). Chronobiology (CB) progressed and was studied in humans for the first time in the 20th century, after which the terms circadian, CB, chronodisruption (CD) and chrononutrition (CN) were invented (1,3,4).

The term BC according to the US National Institute of Health (NIH) (3)refers to the study of physical, mental or behavioral fluctuations that occur within twenty-four hours. Circadian rhythms play a fundamental role in the organism in aspects such as the optimization of nutrients and energy that the body uses for the actions of routine life(5,6). This is shaped and modified by external, non-modifiable signals, such as light and dark times, and environmental signals, or modifiable signals such as dietary pattern or intake (3,6–8). When there is an alteration, maintained over time, of the rhythms and both biological and physiological aspects are modified, the so-called CD is produced (4,5,9–11).

It is not known whether, taking all of the above into account, there are times of the day when, although the net energy load is the same, there is a greater predisposition to weight loss (12–14). It should be noted that the global percentage of people suffering from obesity continues to increase every year (12,15,16).

General Objective:

- To know the relationship between the number and timing of meals and their effect on body composition.

Specific objectives:

- Determine if there are recommendations regarding meal times to promote weight loss.
- Assess how the number of meals influences weight gain or loss.

Chronobiology

The concept of "clock" in this branch of physiology was inspired by Kramer to refer to the compensation made by birds with the sun. The term is currently used to explain the relationship between nature and the internal rhythm that humans present (1,17).

Due to the importance that these circadian rhythms, together with the seasons of the year, have on the organism; living beings, including humans, have been trying to adapt to all the changes that have been occurring. One of the most drastic changes is industrialization, since the number of hours that people spend exposed to artificial lights has increased and, consequently, the incidence of natural light has decreased (1,6,17).

Chronobiology and nutrition

The organ par excellence in charge of the regulatory processes of hunger and satiety in the body is the hypothalamus. Thanks to the latter, with the help of hormones,

peptides and other molecules and nutrients such as glucose or fatty acids, humans are able to distinguish times when they need a caloric intake from those when they do not (8,17).

Many hormones are currently known to be involved in the processes of hunger and satiety, of which three stand out as they have been extensively studied. On the one hand, leptin, secreted by adipocytes when fat levels are increased and responsible for the feeling of satiety. Ghrelin, which is responsible for providing the sensation of hunger and thus inciting food intake, is also important (8,17,18). Thirdly, neuropeptide Y (NPY) is related to the regulation of intake and is responsible, together with ghrelin, for increasing appetite by inciting the initiation of food consumption. The concentrations of these hormones appear to oscillate depending on the time of day, affecting the way in which food is absorbed (6,17,18).

The way in which food assimilation processes could be modified is by modulation of the hypothalamus, pineal gland and thus the CNS. In addition, molecules such as glucose, which is controlled by the hormone insulin and this, in turn, by the CNS, see their absorption modified and slower as the day progresses (11,18,19).

As science has progressed, new concepts have emerged. Due to the need to unify the concepts of circadian rhythms, BC and food, the concepts of CN arise, which refers to the study of nutrients as well as the variability of use throughout the day, and the concept of chronodiet, which is explained as the study to know what are the best times to consume one or other foods (17,20–22).

BC, as mentioned above, refers to the study of changes (physical, mental or behavioral) that occur over the course of a day (17,18). Over time, the human body has seen changes in the way it feeds itself. This change generates DC but, contrary to what one might think, it has not generated alterations in the genes, so that the body has not "adapted" to new habits imposed by the human being himself, such as *social jet lag* (a practice carried out especially in young people with study and nightlife), shift work, high exposure to artificial lights, etc. On the other hand, the epigenetic scope could be affected by this factor, which could lead to changes in gene expression (3,6,17,23).

However, there are other factors that can cause a DC in the body, such as irregular sleep, drastic temperature changes, very frequent meals or a low physical activity routine; these types of practices can be related to changes in the weight of people, especially an increase in weight (6,8,17,18,24).

It was thought that even aspects such as the season of the year could affect weight gain by causing CD, the current evidence does not associate a decrease or increase in weight to these seasonal changes, although the food consumption that the population ingests is different, for the evidence to be firm a greater number of studies are needed (25,26).

Meal times and frequency

Frequency of meals

Meal frequency refers to the number of times meals are eaten during a 24-hour period. The number of intakes during a day has a strong cultural basis, although aspects such as epidemiological studies and scientific evidence provided throughout history have also led to slight modifications in human habits (17,19).

Throughout history, it has been investigated whether food frequency has an effect on human weight. At the beginning of the research, around 1964 and 1965, it was said that a greater number of meals was associated with greater weight loss, with the recommendation being to eat between five and six meals a day. It was also observed that a smaller number of meals per day was associated with a greater predisposition to develop heart disease (7,13,19).

In 1989, the *"Nibbling versus gorging"* study(27) study continues to support the theory that a greater frequency in the number of meals has benefits in terms of lipid profile with a decrease in LDL and total cholesterol.

Research continued and, in 2001, the first evidence began to show that people who ate one or two meals a day were able to lose more weight compared to those who ate three to six meals a day (7,19). From about 2010 onwards, there is a greater variety in the results, some associating a greater loss with a lower frequency of meals and others, on the other hand, with a higher frequency of meals (8,19,28).

In some studies, a lower number of meals was associated with an increased risk of developing some pathologies or Non-Communicable Diseases (NCDs) such as increased risk of cardiovascular pathologies, obesity and lipid profile problems (7,12,29,30). While the randomized crossover study by Belinova L. et al (31) relates lower meal consumption with stabilization of hormone levels (mainly leptin and ghrelin) and thus lower weight gain and development of DM2.

In another study, the frequency of main meals is not mentioned as a promoter of obesity, but rather the number of snacks eaten, suggesting in this case a lower number of snacks as the day progresses (32).

The scientific evidence focuses more strongly on meal timing and less on meal frequency, since the timing of meals has a greater impact on potential CD (8,17).

Food timing

Mealtimes, as well as the number of meals, are closely linked to cultural and family traditions and psychological factors, as shown in Figure 1. (19,33). The timing of intakes has begun to be a predictor of health and a risk factor for the development of NCDs such as obesity (33,34).

Figure 1

Determinants for the food schedule (34)

In the last 5 years, *food timing* has been a topic of study for researchers. There are a variety of results, some of the latest (7,35)there are a variety of results, some of the latest showing that an earlier mealtime window benefits weight loss compared to those who start later. This result is intended to argue that the time at which meals are taken has an effect on body weight (35).

A review, including observational, randomized crossover and longitudinal studies, examines the causal relationship (36)including observational, randomized crossover and longitudinal studies, analyzes the causal relationship between the timing of food consumption, the development of NCDs and weight loss. In this article, the timing of meals was investigated and it was concluded that eating after three o'clock in the afternoon could be a factor that generates weight gain. In addition, taking into account the macronutrients ingested in them could also contribute to greater difficulty in weight loss. The review cites a cultural association (modifiable) with dinner and a more genetic association with the time at which breakfast is eaten, the latter being a possible factor in weight loss (36).

In the case of the studies by Richter et al. (37) and Engin (18)the former a randomized clinical trial and the latter a review including mainly observational studies, concluded that an intake of calories earlier in the day is more important than total calorie intake per se. In both studies, even an increase in the amount of food eaten at dinner was associated with an increased risk of CD and thus of developing metabolic syndrome and/or obesity (18,37). Other interesting aspects mentioned are the association of caloric restriction with CNS activation and the alteration or modification of the timing of intakes with the activation of peripheral clocks (18,37).

Similar results were obtained by Shaw et al. (13)basolo et al. (15)and Dashti et al. (34)in these studies, the first two systematic reviews and the last one a cohort study, a possible improvement in weight loss was seen when the main intake was in the first hours of the day, although without very significant differences in the first two. It is believed that eating in a disorderly manner, without clear schedules and without having any routine can affect the total energy expended and cause changes in appetite and hormones (13).

Some studies make associations between mealtime and peaks in the levels of different hormones. For example, when a peak of melatonin is found in the blood, the amount of food consumed is reduced, with the aim of reducing appetite and thus weight gain. This peak usually coincides, as explained above, with the hours close to bedtime and sunlight disappears (29).

The effect of meal frequency and timing on body weight has also been studied jointly (38). The conclusions reached tilt the balance towards the fact that the time of meals has a greater impact than the frequency of meals on the modification of body weight, with the predominant theory being that if meals are eaten early in the day, they have a preventive effect on weight gain. Despite these results, it is believed that meal frequency may have greater relevance if changes are added as the years go by (8,38).

On the other side of the coin are studies in which there is no significant evidence between eating schedule and weight loss (12,39–41). failing to see a clear association between increased food consumption in the evening, weight gain and the occurrence of NCDs in people with obesity (40). Individual variation among the population, known to be a very heterogeneous group, means that no relevant associations can be observed in terms of greater resistance to weight loss in people who consume greater amounts in the morning versus at night (12,40).

The adaptations that the human body generates during caloric restriction regardless of meal timing make weight loss in obsessive patients more complicated (40). Energy deficit, for some studies, is the sole determinant of weight loss, regardless of other factors such as fasting range or diet quality (41).

Chronotypes

Circadian rhythms are defined in humans by means of the chronotype. This term is defined as the characteristics that an individual possesses in relation to circadian rhythms, which are marked by the schedules and habits of sleep, physical activity, energy, etc. (42,43). The chronotype as such reflects differences in the organism's preference for the time of day's activities.

In humans, chronotype is classified into three broad categories: morning chronotype, evening chronotype and neutral chronotype (39,42–45).

First, the morning chronotype, also known as the morning type, is reflected in people who are more active, both energetically and mentally, in the early hours of the day (39,42,43). Secondly, there are the evening types, the names of chronotype owl or E (evening type) also define them. They are people who have their peak mental and energetic activity in the afternoon (42,43). The last chronotype type is the neutral one, also known as intermediate. They account for 60% of the world's population and are characterized by having no problem adapting to timetables (42,43). From these three types of chronotypes, there are hybrids among them, with different names and characteristics that derive from the main chronotypes (42). As a result of the study of the human chronotype, in the results obtained, differences have been observed in terms of characteristics (such as habits and personality) and other factors such as dietary pattern or the quality of sleep of people depending on their chronotype (39,42,44).

At the beginning, the literature on weight loss and chronotype was practically null, since chronotype was not taken into account as a relevant factor for weight loss and body composition. After a few years, studies began to assess the need to include the chronotype of individuals, as it is believed that it can influence the food metabolism and the eating pattern that is carried out (19,39,42,43).

Currently, it is believed that due to the imposition of both social and work schedules, people with a chronotype E are more vulnerable to the development of NCDs such as obesity and DM2, as well as poorer blood glucose control (43,45).

One of the last studies that have been carried out about the food intake, chronotype and body composition (39)the study concludes that people with a morning chronotype are more likely to gain weight if they eat most of their meals in the afternoon and those with an evening chronotype are more likely to gain weight if they eat most of their meals in the morning.

Method

The present article consists of a bibliographic review of scientific articles to determine whether the timing and/or frequency of meals is related to the decrease in body weight.

For its realization, we proceeded to search for scientific articles on the area to be treated, with preference given to those carried out on human beings. Since not all articles contained information on both issues (frequency and schedule), isolated searches were also conducted in order to find further evidence. For the development of the work, which began on November 5, 2021 and ended on March 29, 2022, publications and books of

interest were consulted, as well as relevant international organizations in reference to the topic of chronobiology and human health. In addition, it was taken into account that the items had an age, except in specific cases, of 5 years, i.e. the range used was from 2017 to 2022. Among the criteria for inclusion of the articles, the impact factor of the journals in which they were published was taken into account, all of them being of scientific relevance and in the first or second quartile. Aspects such as the authors' writing or relevance in the field of research were also taken into account.

The databases used for the bibliographic search are explained below.

1. Pubmed: The start date of the search began on November 5, 2021 and ended on March 29, 2022. As keywords used to search for articles, the following were used:

- *Chronobiology "Cronobiology"*. This search yielded a total of 1989 documents related not only to this term but also to others such as "circadian rhythms". For the screening of the articles, the established inclusion criteria were taken into account, although it is true that since the purpose of this search was to find the origins of this part of science, as well as the history in this respect, after this search, the bibliography of the articles was searched until the first author was found. Therefore, 4 articles were selected that were useful for the literature review process.
- *Food timing and weight balance*: Forty-six articles were obtained, of which 25 were used for the literature review.
- *Food frequency and weight balance"*: A total of 346 articles were found in the search, of which 8 articles were selected at the end, although in the previous search articles were found that dealt with the topic together.
- *Macronutrients and weight balance "Macronutrients and weight balance"*. With these keywords, 646 results were obtained, of which only 6 were used.
- *Human chronotype and weight loss "Human chronotype and weight loss"*. A total of 12 results were obtained for this search, 4 of which were used for this work.

The exclusion criteria mentioned above were applied in these searches.

2. Scielo: The start date of the search began on December 07, 2021 and ended on March 29, 2022. As keywords, the following terms were used in English:

- *Chronobiology "Cronobiology":* A total of 55 articles were obtained, of which only 1 was used.
- *Food frequency and weight loss:* Four articles were obtained, which were not used for the literature review.
- *Meal timing and weight loss "Food timing and weight loss":* Thirty-eight articles were obtained. One article was used, since two others had already been previously selected in Pubmed.

Finally, a total of 49 articles were used for the literature review.

Discussion and conclusions

Chronobiology can be a new aid in the treatment of the population in weight loss and modification of body composition, thus providing evidence to the population with both normal weight and overweight and obesity on the best nutritional approach (19,32).

In reference to meal timing, 10 articles specifically and directly address the possible relationship between meal times and changes in body composition or weight loss. Depending on the study model, 3 are reviews and the rest are experimental, including 3 cohort studies and 4 cross-sectional or randomized crossover studies (8,12,29–32,34,35,46,47). In relation to weight loss and changes in body composition, five of the eight (29,30,32,34,35) studies concluded that there were changes and improvements in weight loss if the timing of meals was taken into account, while the other two concluded that the timing of meals did not affect the body modification of individuals.

Some authors linked this increased predisposition to weight gain to circadian rhythms and hormones released in the body (29,32,34), while others did not investigate this part of physiology but did look at changes in insulin resistance throughout the day (30,35). The parameters to be taken into account in all studies are weight or BMI, some also take into account other hormonal parameters or sleep (29,30,34).

With the results obtained from the articles and systematic reviews, the evidence suggests that meal times do relate to greater or lesser

weight loss.

Regarding the frequency at which meals are taken and the modification of body composition of individuals, 4 articles talked specifically about this aspect, divided according to their approach into 1 systematic review, 1 cross-sectional study, 1 cohort study and 1 randomized crossover study, the last three shown in Table 1 (19,31,38,41).

All of them propose a lower frequency in the number of meals, either so that the hormonal part is modified and regulated (31) as well as for the simple fact that a smaller number of meals implies a lower caloric intake in general (38,41). Like the articles, the review also concludes that a frequency of 2 or 3 meals per day along with the timing and composition of the meals may be a good approach to weight loss. In order to reach these conclusions, some of the studies looked at parameters such as BMI, weight, amount of macronutrients, and even hours of sleep in one of them (38,41). In the case of Belinova L. et al (31) blood markers GLP-1, GIP, PP,PYY, leptin, ghrelin and amylin are used.

The influence of macronutrients is another aspect to take into account when it comes to human body modification. Within the articles that talk about this topic, there are 3, 1 of them is an observational study, a cohort study and a review with meta-analysis (32,48,49).

As for the results obtained in them, the study Xiao et al. (49)it was observed that a distribution of meals, with a higher percentage of consumption centered in the morning, benefited a lower BMI and therefore weight loss and a lower percentage of fat. Regarding macronutrient distribution, the consumption of a higher amount of HC and protein close to bedtime, especially in people with evening chronotypes, increases the chances of obesity.

Although conclusions are drawn in the research, some of the studies see the need for more research in the area in order to reach reliable and scientifically sound conclusions about whether meal timing is associated with improved weight loss or weight gain

(7,12,15,34,40,47). In addition, other factors such as the quantity and quality of sleep and the microbiota should also be investigated as elements that affect weight loss. These factors may not only affect weight loss in situ, but may also have a synergistic effect with the other concepts explained above, such as the case of feeding schedules or frequency (19,24).

Scientific evidence suggests that the timing of meals influences the weight of patients as well as possible variations in body composition, and factors such as chronotype modify the assimilation of nutrients and thus the total energy balance. The frequency of meals, although not as recently studied as the timing, is also relevant in the nutritional approach of patients, and the literature shows that a smaller number of meals can be a good nutritional approach for weight loss and reduction of the fat percentage.

Reference	Type of study	Population	Features	Parameters	Results
Kahleova H. et al. 2017. (38)	Cohort study	50.660 subjects	Weight loss was observed in people who consumed 1 or 2 meals per day compared to those who consumed 3 meals per day.	BMI, age, amount of macronutrients in the diet, as well as hours of sleep, sex, and aspects related to alcohol and tobacco consumption were taken into account.	Eating less often, not snacking between meals, eating breakfast as a small meal first thing in the morning can be an effective strategy for weight loss.
Belinova L. et al. 2017. (31)	Randomized crossover study	54 patients with DM2	Patients between 30 and 70 years of age diagnosed with DM2 diagnosed more than one year ago, who were administered a hypocaloric diet for 12 weeks.	Observation of GLP-1, GIP, PP, PYY, leptin, ghrelin and amylin markers.	For patients who present with DM2 as well as overweight, a two-meal-a-day nutritional approach may be more effective for weight loss.
Zeballos E. et al. 2020. (41)	Cross-sectional study	23488 subjects	Adults over 18 years of age who will submit two records 24h.	Caloric count according to whether subjects did not eat breakfast, lunch or dinner	The elimination of the evening meal results in a decrease in caloric intake and thus greater weight loss, but there is also a loss in nutritional variety (especially if breakfast is skipped) which could negatively affect health.

Even taking all these results into account, a greater number of supporting studies are needed to obtain more current scientific evidence.

After reading the articles, some limitations could be taken into account for the elaboration of future research, the following points are proposed:

- The studies do not take into account the time of the year at the time of the intervention, taking into account the solar time at the time of the studies could be a good approach, since summer and winter time advance or delay the day by one hour; therefore, the circadian rhythm may be altered. Meal times such as

breakfast and dinner are most likely to be affected by light/dark times causing some meals to be eaten at night.

- In the studies in which the time is taken into account, other relevant factors such as the inclusion in the study of the distribution of macronutrients and chronotypes are not taken into account in order to know if, taking into account all these parameters, the time can influence the body composition of the subjects.
- Finally, no specific methodology has been created in which all the studies observe the same parameters and thus a comparison can be made and conclusions reached with greater reliability.

References

(1). Kuhlman SJ, Craig LM, Duffy JF. Introduction to Chronobiology. Cold Spring Harb Perspect Biol. September 2018;10(9):a033613.
(2). de Mairan JJ. Observation botanique. Hist Acad Roy Sci. 1729;35-6.
(3). NIH. Ritmos circadianos [Internet]. 2021 [cited February 15 2022]. Available in: https://www.nigms.nih.gov/education/fact-sheets/Pages/circadian-rhythms-spanish.aspx
(4). Aschoff J. On the relationship between motor activity and the sleep-wake cycle in humans during temporal isolation. J Biol Rhythms. 1993;8(1):33-46.
(5). Erren TC, Reiter RJ, Piekarski C. Light, timing of biological rhythms, and chronodisruption in man. Naturwissenschaften. November 2003;90(11):485-94.
(6). J Sánchez Muniz F. Clock Genes, Chronodisruption, Nutrition and Obesity. Curr Res Diabetes Obes J [Internet]. July 31 2017 [cited February15 2022];3(2). Disponible en: http://juniperpublishers.com/crdoj/CRDOJ.MS.ID.555607.php
(7). Adafer R, Messaadi W, Meddahi M, Patey A, Haderbache A, Bayen S, et al. Food Timing, Circadian Rhythm and Chrononutrition: A Systematic Review of Time-Restricted Eating's Effects on Human Health. Nutrients. December 8 2020;12(12):E3770.
(8). Poggiogalle E, Jamshed H, Peterson CM. Circadian regulation of glucose, lipid, and energy metabolism in humans. Metabolism. July 2018;84:11-27.
(9). Pittendrigh CS. Circadian rhythms and the circadian organization of living systems. Cold Spring Harb Symp Quant Biol. 1960;25:159-84.
(10). Aschoff J, Gerecke U, Wever R. Desynchronization of human circadian rhythms. Jpn J Physiol. August 15 de 1967;17(4):450-7.
(11). Challet E. The circadian regulation of food intake. Nat Rev Endocrinol. July 2019;15(7):393-405.
(12). Jacob R, Tremblay A, Panahi S, Provencher V, Drapeau V. Is the timing of food intake a potential indicator of low weight loss responders? A secondary analysis of three weight loss studies. Clin Obes. June 2020;10(3):e12360.
(13). Shaw E, Leung GKW, Jong J, Coates AM, Davis R, Blair M, et al. The Impact of Time of Day on Energy Expenditure: Implications for Long-Term Energy Balance. Nutrients. October 6 2019;11(10):E2383.
(14). WHO. Body mass index - BMI [Internet]. [cited ferbuary 15 2022]. Available in: https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi
(15). Basolo A, Bechi Genzano S, Piaggi P, Krakoff J, Santini F. Energy Balance and Control of Body Weight: Possible Effects of Meal Timing and Circadian Rhythm Dysregulation. Nutrients. Available 19 2021;13(9):3276.

(16). Freire R. Scientific evidence of diets for weight loss: Different macronutrient composition, intermittent fasting, and popular diets. Nutr Burbank Los Angel Cty Calif. January 2020;69:110549.
(17). Calvo Fernández JR, Gianzo Citores M, Calvo Fernández JR, Gianzo Citores M. Los relojes biológicos de la alimentación. Nutr Hosp. 2018;35(SPE4):33-8.
(18). Engin A. Circadian Rhythms in Diet-Induced Obesity. Adv Exp Med Biol. 2017;960:19-52.
(19). Paoli A, Tinsley G, Bianco A, Moro T. The Influence of Meal Frequency and Timing on Health in Humans: The Role of Fasting. Nutrients. March 28 2019;11(4):719.
(20). Leech RM, Worsley A, Timperio A, McNaughton SA. Temporal eating patterns: a latent class analysis approach. Int J Behav Nutr Phys Act. January 7 2017;14(1):3.
(21). Nakamura K, Nakamura Y. Hunger and Satiety Signaling: Modeling Two Hypothalamomedullary Pathways for Energy Homeostasis. BioEssays News Rev Mol Cell Dev Biol. August 2018;40(8):e1700252.
(22). Pot GK. Sleep and dietary habits in the urban environment: the role of chrono-nutrition. Proc Nutr Soc. August 2018;77(3):189-98.
(23). Schutz Y. Macronutrients and energy balance in obesity. Metabolism. September de 1995;44(9 Suppl 3):7-11.
(24). Thomas EA, Zaman A, Cornier MA, Catenacci VA, Tussey EJ, Grau L, et al. Later Meal and Sleep Timing Predicts Higher Percent Body Fat. Nutrients. December 29 2020;13(1):E73.
(25). Stelmach-Mardas M, Kleiser C, Uzhova I, Peñalvo JL, La Torre G, Palys W, et al. Seasonality of food groups and total energy intake: a systematic review and meta-analysis. Eur J Clin Nutr. June 2016;70(6):700-8.
(26). Yoshimura E, Tajiri E, Hatamoto Y, Tanaka S. Changes in Season Affect Body Weight, Physical Activity, Food Intake, and Sleep in Female College Students: A Preliminary Study. Int J Environ Res Public Health. November 24 de 2020;17(23):E8713.
(27). Jenkins DJ, Wolever TM, Vuksan V, Brighenti F, Cunnane SC, Rao AV, et al. Nibbling versus gorging: metabolic advantages of increased meal frequency. N Engl J Med. October 5 1989;321(14):929-34.
(28). Zerón-Rugerio MF, Díez-Noguera A, Izquierdo-Pulido M, Cambras T. Higher eating frequency is associated with lower adiposity and robust circadian rhythms: a cross-sectional study. Am J Clin Nutr. October 23 2020;nqaa282.
(29). McHill AW, Phillips AJ, Czeisler CA, Keating L, Yee K, Barger LK, et al. Later circadian timing of food intake is associated with increased body fat. Am J Clin Nutr. November 2017;106(5):1213-9.
(30). Wehrens SMT, Christou S, Isherwood C, Middleton B, Gibbs MA, Archer SN, et al. Meal Timing Regulates the Human Circadian System. Curr Biol CB. June 19 de 2017;27(12):1768-1775.e3.
(31). Belinova L, Kahleova H, Malinska H, Topolcan O, Windrichova J, Oliyarnyk O, et al. The effect of meal frequency in a reduced-energy regimen on the gastrointestinal and appetite hormones in patients with type 2 diabetes: A randomised crossover study. PloS One. 2017;12(4):e0174820.
(32). Vilela S, Oliveira A, Severo M, Lopes C. Chrono-Nutrition: The Relationship between Time-of-Day Energy and Macronutrient Intake and Children's Body Weight Status. J Biol Rhythms. June 1 de 2019;34(3):332-42.

(33). Dashti HS, Scheer FAJL, Saxena R, Garaulet M. Timing of Food Intake: Identifying Contributing Factors to Design Effective Interventions. Adv Nutr Bethesda Md. July 1 2019;10(4):606-20.
(34). Dashti HS, Gómez-Abellán P, Qian J, Esteban A, Morales E, Scheer FAJL, et al. Late eating is associated with cardiometabolic risk traits, obesogenic behaviors, and impaired weight loss. Am J Clin Nutr. October 6 de 2020;nqaa264.
(35). Hatanaka M, Hatamoto Y, Tajiri E, Matsumoto N, Tanaka S, Yoshimura E. An Earlier First Meal Timing Associates with Weight Loss Effectiveness in A 12-Week Weight Loss Support Program. Nutrients. January 7 de 2022;14(2):249.
(36). Lopez-Minguez J, Gómez-Abellán P, Garaulet M. Timing of Breakfast, Lunch, and Dinner. Effects on Obesity and Metabolic Risk. Nutrients. November 1 de 2019;11(11):E2624.
(37). Richter J, Herzog N, Janka S, Baumann T, Kistenmacher A, Oltmanns KM. Twice as High Diet-Induced Thermogenesis After Breakfast vs Dinner On High-Calorie as Well as Low-Calorie Meals. J Clin Endocrinol Metab. March 1 2020;105(3):dgz311.
(38). Kahleova H, Lloren JI, Mashchak A, Hill M, Fraser GE. Meal Frequency and Timing Are Associated with Changes in Body Mass Index in Adventist Health Study 2. J Nutr. September 2017;147(9):1722-8.
(39). Maukonen M, Kanerva N, Partonen T, Männistö S. Chronotype and energy intake timing in relation to changes in anthropometrics: a 7-year follow-up study in adults. Chronobiol Int. January 2019;36(1):27-41.
(40). Fong M, Caterson ID, Madigan CD. Are large dinners associated with excess weight, and does eating a smaller dinner achieve greater weight loss? A systematic review and meta-analysis. Br J Nutr. October 2017;118(8):616-28.
(41). Zeballos E, Todd JE. The effects of skipping a meal on daily energy intake and diet quality. Public Health Nutr. December 2020;23(18):3346-55.
(42). Montaruli A, Castelli L, Mulè A, Scurati R, Esposito F, Galasso L, et al. Biological Rhythm and Chronotype: New Perspectives in Health. Biomolecules. March 24 2021;11(4):487.
(43). González JAO, Reboredo TB, Pliego MV, Rodríguez GS, Espinosa CB, Fernández MSP, et al. Cronotipo, composición corporal y resistencia a la insulina en estudiantes universitarias. Rev Cuba Aliment Nutr. 2018;28(2):272-86.
(44). Machado Rojas A, Díaz López IR, de la Torre Santos ME. Un breve acercamiento al cronotipo humano. Medicentro Electrónica. March 2018;22(1):74-6.
(45). Hashemipour S, Yazdi Z, Mahabad N. Association of Evening Chronotype with Poor Control of Type 2 Diabetes: Roles of Sleep Duration and Insomnia Level. Int J Endocrinol Metab. July 2020;18(3):e99701.
(46). Hawley JA, Sassone-Corsi P, Zierath JR. Chrono-nutrition for the prevention and treatment of obesity and type 2 diabetes: from mice to men. Diabetologia. November 2020;63(11):2253-9.
(47). Ravussin E, Beyl RA, Poggiogalle E, Hsia DS, Peterson CM. Early Time-Restricted Feeding Reduces Appetite and Increases Fat Oxidation But Does Not Affect Energy Expenditure in Humans. Obes Silver Spring Md. August 2019;27(8):1244-54.
(48). Hall KD, Guo J. Obesity Energetics: Body Weight Regulation and the Effects of Diet Composition. Gastroenterology. May 2017;152(7):1718-1727.e3.
(49). Xiao Q, Garaulet M, Scheer FAJL. Meal timing and obesity: interactions with macronutrient intake and chronotype. Int J Obes. September 2019;43(9):1701-11.

Date received: 06/02/2023
Revision date: 09/03/2023
Date of acceptance:03/27/2023