

## **Effect of meal frequency and meal timing on overweight and obesity**

### **Efecto que tienen la frecuencia y horarios de las ingestas sobre el sobrepeso y obesidad**

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#### **ABSTRACT**

**Keywords:**

chrononutrition, intake frequency, meal timing, circadian rhythms.

In recent years, there has been an increased interest in understanding which factors, beyond caloric intake, related to daily eating habits affect weight gain or the difficulty in losing weight, leading to the emergence of chrononutrition. This topic is becoming increasingly relevant as a potential explanation for weight gain in adults. The objective of this article is to compile scientific evidence to evaluate the effect of meal timing and frequency on overweight and obesity in adults. This is a literature review, using 35 articles, with PubMed and Google Scholar being the main databases used. The study results indicate that having a higher number of meals per day is associated with a lower BMI and better anthropometric outcomes. Additionally, following a morning meal schedule promotes greater weight loss and is also associated with a lower BMI. Moreover, studies reveal that a morning meal schedule improves hormonal signals, exerting control over intake signals. In conclusion, more evidence is needed to confirm the results found, with more studies of higher quality. Nevertheless, the evidence suggests that having more meals, earlier in the day, with a higher caloric load in the morning, could be key for improvements in anthropometric measures, weight, and BMI.

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#### **RESUMEN**

**Palabras clave:**

crononutrición, frecuencia de ingesta, horario de ingesta, ritmos circadianos.

En los últimos años, ha incrementado el interés por conocer qué condicionantes acerca de la alimentación diaria afectan al incremento o difícil disminución de peso, habiendo surgido así la crononutrición. Este tema es cada vez de más relevancia como búsqueda de una posible explicación al aumento de peso en adultos. El objetivo de este artículo es recopilar evidencia científica para evaluar el efecto que tiene el momento de ingesta y la frecuencia de las tomas sobre el sobrepeso y la obesidad en adultos. Se trata de una revisión bibliográfica, para la que se usaron 35 artículos, siendo Pubmed y Google Académico las principales bases de

datos utilizadas. Los resultados de los estudios señalan que realizar un mayor número de ingestas en el día se relaciona con menor IMC y mejores resultados antropométricos; además de que llevar a cabo un horario matutino de comidas promueve mayores pérdidas de peso y se relaciona igualmente con un menor IMC. Además, estudios revelan que el horario matutino mejora las señales hormonales, ejerciendo un control sobre las señales de ingesta. Como conclusión, sería necesaria más evidencia para poder confirmar los resultados encontrados. No obstante, la evidencia apunta a que realizar más ingestas, en un horario temprano, y con una mayor carga calórica en la mañana, podrían ser claves para mejoras antropométricas, del peso y del IMC.

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## **Introduction**

Obesity is known to be an important risk factor for certain diseases such as type 2 diabetes mellitus, arterial hypertension, cardiovascular risk or certain types of cancer, in addition to producing a notable decrease in the quality of life of those who suffer from it (1).

For decades, this condition has been increasingly prevalent, mainly in developed Western countries, and is now a real public health problem. Thus, whereas 40 years ago the prevalence was 1% in childhood, 3% in men and 6% in women, today it is around 6-8%, 6% and 15%, respectively, mainly due to lifestyle changes (2).

The usual treatments have focused on lifestyle interventions, which may interfere with diet and physical activity. Diet is an essential factor in weight control in people who are overweight or obese, and until now there have been several main conditioning factors to combat it: the reduction of the total daily caloric intake and the importance of the macronutrients in the diet (3). In recent years, there has been an increased interest in learning about other determinants of the daily diet that affect to some extent the increase or difficult decrease in weight, and thus chrononutrition has emerged (4).

The term chrononutrition refers to the relationship between biological rhythms and food and nutrition. Circadian rhythms influence food intake and fasting through the internal biological clock; conversely, disordered eating can disrupt internal clocks. Thus, chrononutrition encompasses three dimensions of eating behavior: frequency, regularity and timing. There is increasing evidence and of higher quality that chrononutrition, taking into account any of its dimensions, would have an impact on the metabolic health of individuals, and ultimately on the well-being and general health of the subjects. Thus, the relationship of circadian rhythms and diet to unwanted weight gain and, ultimately, to overweight and obesity is being studied.

## **Method**

In this literature review, a number of papers have been examined, including different articles that analyze the relationship between the number of daily intakes and anthropometry, as well as the time of day when intakes are taken and anthropometry (weight, BMI, waist-hip ratio...).

The search for articles and other publications related to the developed topic began on February 20, 2024 and ended on April 30, 2024. In order to carry out this study, an exhaustive search of multiple publications, all of them in digital format, has been carried out in different databases. The databases that were used to start the search were:

- Pubmed: the following filters were established: free full text, maximum 5 years old (2019-2024) and written in British English. For the search for studies, the keywords used for the search were, in MeSH terms:
  - Meal frequency AND Obesity: a total of 69 studies were found, of which 1 was used due to its relevance and for meeting the aforementioned inclusion criteria.
  - Meal frequency AND overweight: a total of 57 studies were found, of which 1 was used because of its relevance and because it met the inclusion criteria mentioned.
  - Meal timing AND Obesity or overweight: a total of 23 studies were found, of which 3 were used because of their relevance and because they met the inclusion criteria mentioned above.
  - Chrononutrition AND body composition: a total of 2 studies were found, of which 1 was used because of its relevance and because it met the inclusion criteria mentioned.

For the article search, in general, for the theoretical framework, the keywords used were:

- Chrononutrition: a total of 163 articles were found, of which 2 were used because of their relevance and because they met the inclusion criteria mentioned above.
  - Chronobiology: a total of 1556 articles were found, of which 6 were used because of their relevance and because they met the inclusion criteria mentioned above.
  - Obesity risk factors: a total of 23492 articles were found, of which 8 were used because of their relevance and because they met the inclusion criteria mentioned.
  - Obesity epidemiology: a total of 28437 articles were found, of which 3 were used because of their relevance and because they met the inclusion criteria mentioned.
  - Circadian rhythms: a total of 8170 articles were found, of which 3 were used due to their relevance and because they met the aforementioned inclusion criteria.
  - Circadian rhythms and obesity: a total of 570 articles were found, of which 3 were used because of their relevance and because they met the inclusion criteria mentioned.
- Google Scholar: a seniority of 5 years (from 2019) was established as a filter. The keywords used for the search were:
    - Meal timing and obesity / overweight: a total of 17,000 articles were found of which 4 studies were used due to their relevance and for meeting the inclusion criteria mentioned above.

Finally, 35 articles were used for the review.

## **Results**

Most of the studies reviewed agree that the time of day and frequency of intakes could have an effect on multiple parameters, including body composition and anthropometry, and therefore on obesity or overweight.

Analyzing the studies that refer to the frequency of intakes, two of them (26,27) have a direct bearing on the issue, while the other (28) evaluates a fasting method that indirectly implies a lower number of daily intakes. Both the Dote-Montero et al. (26) and Ha and Song (27) conclude that the more meals eaten, the lower the obesity and BMI; however, Dote-Montero et al. (26) only found this relationship in the case of women, while that of Ha and Song (27) in both sexes. This could be due to the fact that the first (26) has 118 participants, of which practically  $\frac{2}{3}$  correspond to women, and therefore it is easier to find a relationship than in the case of men who only have 36 participants. In addition, this is a cross-sectional study, so it is not able to establish causal relationships and the information provided may not be accurate. Although Ha and Song's (27) agrees that increasing the number of intakes is related to a reduction in obesity, it indicates that it would be from 8 or more intakes per day, as compared to 4 or less, which is out of the ordinary and unrealistic.

Wilkinson et al. (28) conclude that fasting, limiting the intake until 14h, reduces the weight of the participants by up to 3%; however, they only have 19 participants, which is a very limited number of subjects. Moreover, it does not directly evaluate the number of intakes nor does it provide any specific data in this regard, but only indicates that fewer intakes are made, so the results are not very specific and could be unreliable since they have been carried out with such a small sample.

Likewise, the studies by Ha and Song (27) and Dote-Montero et al. (26) are based on self-reported questionnaires of the "24-hour dietary record" type, specifically for a single day; therefore, even if the participants tried to include their usual diet in the record, there could be losses of information, or a non-representative diet because it is a single day.

It should be taken into account that the study by Wilkinson et al (28) is the only one that includes participants with metabolic syndrome and obesity, while the others (26,27) include healthy participants, which could explain the differences in the results obtained (so that in healthy subjects increasing the number of intakes is related to better anthropometric results, and in overweight/obese subjects these intakes should be limited).

However, the number of recent studies found on the relationship between the number of intakes and weight loss or gain are scarce, and have numerous limitations such as few participants (28), not being able to establish causal relationships (26) or lack of information (26-28).

**Table 1.** Studies relating the frequency of ingestion to influential parameters on body weight

<b>Author, year</b>	<b>Type of study</b>	<b>Subjects/groups</b>	<b>Main results</b>	<b>Conclusions</b>
Dote-Montero et al., 2023(26)	Cross-sectional study	118 young adults (82 women and 36 men) participated  Age = 22 ± 2 years BMI = 25,1 ± 4,6 kg/m <sup>2</sup>	Meal timing is not related to anthropometry or body composition.  Skipping breakfast, and thus having a longer feeding window and fewer meals, is associated with poorer body composition in women and higher BMI.	It was concluded that eating more meals and not skipping breakfast is related to less obesity and BMI in women.
Ha and Song, 2019(27)	Cross-sectional study	Among 27220 initial participants, 14279 subjects (8425 women and 5854 men) were finally included in the analysis.  Mean age = 41.1 years in men; 41.7 years in women.	Men with more daily intakes (8 per day) have less abdominal obesity than men with approximately 4 intakes per day.  In addition, women who eat in the morning have less abdominal obesity, and men who eat in the evening have more metabolic abnormalities (including obesity).	It was concluded that having a greater number of intakes reduces metabolic abnormalities, including obesity.
Wilkinson et al., 2020(28)	Clinical trial	Initially, 35 subjects participated, of whom 19 (13 men and 6 women) with metabolic syndrome were finally included.  Average age = 59 ± 11.14 years	The participants' body weight was reduced by about 3%.	It was concluded that limiting intake to fewer meals per day was significantly associated with weight loss and cardiometabolic improvements.

Regarding the relationship between the timing of daily intakes and body weight, a greater number of recent studies have been found. Most of these agree that an early feeding schedule is associated with either greater weight loss or lower weight, BMI or other parameters (such as hunger signals) than a late feeding schedule (27,29-34). However, other studies deny that eating at certain times is associated with greater weight loss or lower BMI (26,35). However, it is necessary to go deeper and analyze how each of them has obtained their results and why they are different.

Several of these studies are randomized controlled trials, in which participants are randomly divided into groups that follow a diurnal or delayed diet for a given period of time, in order to ultimately evaluate the body changes produced in each group and compare them with each other (29,30). However, in one of them, the early and late groups differed only by the time of the beginning of intake, resulting in a much higher weight loss in the early group compared to the late group (and taking into account that physical activity, caloric intake and macronutrient intake were the same in both groups) (29). In the other study, the intake of the early and late groups is limited to specific schedules (early intake from 8-19h and late intake from 12-23h), but also very controlled in terms of caloric and macronutrient intake and physical activity. Similarly, body weight at the end of the study was lower in the early group than in the late group, and other parameters such as fat oxidation and insulin sensitivity improved (30).

However, this latest study (30) suggests that hormones are not affected and therefore we consider that they are not responsible for these differences. One possible explanation that early eating leads to improvements in body weight is the first meal of the day, which alone would not improve weight loss, but the habit of eating early increases the likelihood of weight loss. It should be noted that one of these studies (29) was conducted in overweight/obese adults and the other (30) in normal-weight adults. But these studies only control for the timing of intake and not the intake itself (29,30).

The study by Ruddick-Collins et al. (35) followed the same line as the previous ones and divided the participants into two groups, but in this case the schedule remained the same in both and what varied was the caloric load in each intake (more loaded in the first intake or more loaded in the last), similar to that of Gu et al. (34) in which two groups had four meals, but the last two were different in caloric load. In the first of these (35), weight loss was practically identical, with no significant differences, but a lower sensation of hunger, thirst or desire to eat was observed in the diet loaded in the morning compared to the one loaded in the evening (explained by hormonal changes and slower gastric emptying). The other (34), on the other hand, did not directly evaluate the effect on obesity, but did conclude that the heavier diet at night induced an anabolic state during sleep that favored the increase in lipid storage, ultimately promoting obesity. However, this last study had only 20 healthy, normal-weight participants, so the conclusions are controversial and more studies should be conducted with a larger number of participants. Even so, the results are likely to be reliable as they have been performed through a laboratory in a highly controlled manner, eliminating possible biases. Similarly, that of Ruddick-Collins et al. (35) was carried out with only 30 participants, but in this case with overweight or obesity, and presented possible biases due to non-compliance with what was proposed by the participants (there was no rigorous control).

Along the same lines as the above, other studies have focused on evaluating hunger or satiety signals, food cravings, as well as hormonal responses to eating at certain times, as possible explanations for unwanted weight gain (31,32). In their research, Vojovic et al. (31) studied how schedules affect the control of intake, energy expenditure and

adipose tissue in overweight or obese subjects, obtaining as results that eating late (or having a late schedule of intakes) produced less satiety and more hunger; in addition to a significant reduction in energy expenditure compared to an early schedule. This study went a step further and evaluated the regulation of adipose tissue, observing a reduction in lipolysis and an increase in lipogenesis. This was also carried out through a biopsy, which is associated with reliable results. However, it was composed of only 16 participants. Another similar study (32) also focused on the signals after late-hour ingestion, but in this case it went a step further and differentiated the participants into two groups according to their chronotype (assessed by a questionnaire), and both groups performed both early and late hours. The results regarding late hours were consistent with the previous study (31), being related to less appetite and more satiety. In addition, it was concluded that early chronotype was related to lower BMI and greater satiety after meals. In this case, the study by Beaulieu et al. (32) was composed of more participants and healthy subjects, so we can conclude that in both healthy and overweight or obese subjects the earlier schedule would improve intake signals and hormonal responses; and regarding the chronotype more studies would be needed.

Two studies (26,27) focused on assessing anthropometric and body composition outcome through 24-hour reminders that documented the participants, and thus their meals and the exact times at which they were eaten were known. With this information, a series of conclusions were drawn. In this case, while the study by Ha and Song (27) showed that eating more at night than in the morning influences the development of metabolic syndrome, in addition to the fact that eating at night is related to higher weight and worse body composition in men. However, Dote-Montero et al (26) found no association between the schedule and body composition and anthropometry. However, it should be taken into account that both are cross-sectional studies, which prevents the establishment of causal relationships (cause-consequence), in addition to the fact that the 24-hour reminders in both studies were for a single day, which may generate certain information biases (non-representativeness of the general intake, forgetfulness, etc.).

It is surprising that the study by Ha and Song (27) shows an association between nocturnal intake and worse anthropometry only in men. One possible explanation is that men tend to be greater night eaters than women, and in addition to foods with a higher caloric load, it could even be associated with alcoholism and smoking.

However, both studies (26,27) are rather incomplete and leave a lot of information unresolved, so more should be done to reach more reliable and conclusive results.

Finally, Barring and Beresford (33), in their randomized controlled trial, focused on how snacking promoted obesogenic behaviors, and how it affected the timing of snacking. The results suggest, like others cited above, that more morning and even midday snacking is associated with lower BMI and obesogenic behavior compared to evening snacking. However, the composition of these snacks (which in the evening tend to be higher in calories than those in the morning, which are more composed of fruit) was not evaluated. That is, it could be that the relationship was not directly due to the pecks, but to the composition of the pecks.

It should be noted that several of these studies take into account "early" and "late" schedules, which vary greatly from one study to another, depending on the habits and customs of the countries of origin of the studies. Thus, according to each study it is established that "morning feeding" is at 5-9 hours (27), 8-10 hours (32) or 7-8 hours (35), and "evening feeding" at 18-21 hours (27), 16-18 hours (32); as well as "daytime feeding" from 8-19 hours and "delayed feeding" from 12-23 hours in the study of Allison et al. (30);

or the study by Barrington and Beresford (33) that establishes that "snacking in the evening" is if it is done after 4:30 pm.



**Table 2.** Studies relating the timing of intakes to influential parameters on body weight

<b>Author, year</b>	<b>Type of study</b>	<b>Subjects/groups</b>	<b>Main results</b>	<b>Conclusions</b>
Hatanaka et al., 2022(29)	Randomized controlled trial	Ninety-seven adults (51 men and 46 women) were studied, of whom 85 (43 men and 42 women) were included  Age = 47.6 ± 8.3 years BMI = 25.4 ± 3.7 kg/m <sup>2</sup>	Of the relationship between pre-intervention meal timing and weight change, only the start of the feeding window was positively correlated with the rate of weight change in both sexes. The rate of weight change was -3.8 ± 2.7% in the early group and -2.2 ± 2.5% in the late group.	The rate of weight loss in the early group was significantly higher than in the late group. It was concluded that early feeding window initiation was associated with weight loss.
Dote-Montero et al., 2023(26)	Cross-sectional study	118 young adults (82 women and 36 men) participated  Age = 22 ± 2 years BMI = 25.1 ± 4,6 kg/m <sup>2</sup>	Meal timing is not related to anthropometry or body composition.  Skipping breakfast, and thus having a longer feeding window and fewer meals, is associated with poorer body composition in women and higher BMI.	It was concluded that there is no significant relationship between meal timing and anthropometry and body composition.
Barrington and Beresford et al., 2019(33)	Randomized controlled trial	Employees from 34 different workplaces in Seattle. Initially, 3054 subjects participated, but during follow-up, 1151 subjects (of different sexes, BMI, cc, ethnicity) remained  Average age = 43 years	Subjects with more morning snacking had lower BMI and higher fruit and vegetable intake, as did those with more midday snacking. However, those who snack more in the evening have a higher BMI and obesogenic dietary index.	The authors concluded that snacking is related to obesogenic behaviors, mainly if done at night (higher BMI, cc, less fruit and vegetable intake)
Wilkinson	Clinical trial	Initially, 35 subjects	The participants' body weight was reduced by	It was concluded that limiting intake after

n et al., 2020(28)		participated, of whom 19 (13 men and 6 women), all with metabolic syndrome, were included.  Average age = 59 ± 11.14 years	about 3%.	14H was significantly related to weight loss and cardiometabolic improvements.
Allison et al., 2021(30)	Randomized crossover trial	29 initial participants, of which 12 completed the study and provided eligible data (7 males and 5 females)  Age = 26.3 ± 3.4 years  BMI = 21.9 ± 1.7 kg/m <sup>2</sup>	-Body weight is lower in diurnal than in retarded individuals -Resting energy expenditure and respiratory quotient is lower in diurnal and higher in tardive, which implies lower fat oxidation in tardive -Total cholesterol and triglycerides are higher in late bloomers (but HDL and LDL improve) -There is a slight increase in adiponectin in tardigrade (improvement) -Fasting glucose and insulin, and insulin resistance are lower in diurnal -Regarding melatonin, cortisol, leptin, ghrelin and glucose, there are no significant differences between groups	It was concluded that eating at earlier hours leads to improvements in weight, insulin resistance, fat oxidation, fasting glucose, insulin, triglycerides and total cholesterol. However, HDL and LDL, and adiponectin, improved in the late group. Hormones are not affected.  Therefore, the authors conclude that late feeding has adverse effects on weight and metabolic parameters in general, independent of energy intake, PA or sleep.
Ruddick-Collins et al., 2022(35)	Randomized controlled trial	30 obese/overweight subjects (16 males and 14 females)  Average age = 50.9 ± 2.1 years  BMI = 32.5 ± 0.7 kg/m <sup>2</sup>	-Almost identical weight losses (Morning D.-3.3 kg; Late D.-3.38 kg)  -D.Morning scored significantly lower in hunger, food craving and thirst → more hormonal changes (hunger suppression, ghrelin and satiety hormone increase), and slower gastric emptying than D.Late)  -No alteration of energy expenditure (PA and	Study concludes that calorie utilization does not vary throughout the day and that it does not matter at what time of the day you eat more or fewer calories → there will not be more loss of calories from eating larger meals in the morning as suggested by previous studies

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intake being the same in both groups)				
Vujović et al., 2022(31)	Randomized controlled trial	16 participants (11 men and 5 women)  Age = $37.3 \pm 2.8$ years BMI = $28.7 \pm 0.6$ kg/m <sup>2</sup>	<p>-Regarding hunger/appetite, measured on the VAS scale, late intake showed a higher hunger score (&gt; 50) compared to early intake (10-20)</p> <p>-Hormones (leptin, ghrelin and ghrelin:leptin ratio) were studied every hour of each day: leptin decreased 6% and ghrelin:leptin ratio increased 12%; during wakefulness, leptin decreased 16% and ghrelin:leptin ratio increased 34%; and during sleep, leptin increased 10% and ghrelin and ghrelin:leptin ratio decreased 13 and 18%, respectively</p> <p>-GE decreased significantly in late intake (5.03%) with respect to early intake (during wakefulness) and body temperature (BT) decreased during sleep</p> <p>-Late ingestion increased activity of lipogenesis genes and decreased activity of genes responsible for lipolysis</p>	Eating late consistently alters the regulatory functions of intake, energy expenditure and body composition, favoring weight gain and body fat.
Gu et al., 2020(34)	Randomized controlled trial	20 healthy subjects (10 males and 10 females)  Age = $26.0 \pm 0.6$ years  BMI = $23.2 \pm 0.7$ kg/m <sup>2</sup>	<p>-Peak glucose max after dinner: higher GT (<math>150.3 \pm 5.6</math> mg/dL) than GR (<math>127.0 \pm 4.5</math> mg/dL)</p> <p>after breakfast: further increase of insulin and glucose in GT</p> <p>mean blood glucose significantly higher in GT (<math>105.8 \pm 2.3</math> mg/dL) than in GR (<math>99.8 \pm 2</math> mg/dL)</p> <p>-TG in GR peak max 1h after dinner, but does</p>	It was concluded that the increased caloric load late in the day causes an anabolic state that favors lipid storage, so that in a chronic form it may favor the development of obesity.

not rise after dinner  
in peak GT max 1 hour after snack, still rising  
after dinner

-Lower AG oxidation at 4h in GT (74.5+-5.7%)  
than in GR (84.5 +-5.2%)

-Higher mean cortisol in GT (11.4 +- 0.6  
microg/dL) than GR (10.8 +- 0.5 microg/dL)

Beaulieu et al., 2020 (32)	Laboratory study	50 participants, including 44 adults between the ages of 18 and 25 years old	Eating early meals reduced appetite, increasing satiety. Subjects with early chronotype had lower BMI than those with late chronotype, as well as a greater feeling of satiety after meals.	It is concluded that early meals (8-10H) result in lower post-meal appetite and greater satiety, as well as less desire to eat fatty foods. In addition, it is also concluded that the early chronotype is related to lower BMI compared to the late chronotype, greater satiety after meals and lower desire to eat fatty foods.
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## **Discussion and conclusions**

After the analysis carried out in this work, it is important to emphasize that there is still much to investigate and to know in order to reach reliable conclusions about how much to eat and at what times of the day to achieve effective weight loss (or to avoid unwanted weight gain).

So far and with the results of the studies analyzed, it could be considered that having a greater number of daily intakes is recommended to obtain improvements in the weight and/or BMI of the subjects, compared to having fewer intakes. But it is not clear what number of intakes we are talking about, since the present studies are not very concise and do not reach the same conclusions as to the exact number of daily intakes.

An early schedule could also be considered for successful weight loss in cases of overweight or obesity, and for better anthropometric results (BMI, waist-to-hip ratio, body fat). From the studies analyzed, it could be affirmed that the intake signals (hunger and satiety) and the desire to eat obtain better results when intakes are made at early versus late times. However, it is not only the timing of intakes that should be taken into account, but also the caloric load of those intakes, as some studies suggest that a higher late caloric load promotes a state of overweight/obesity, while a higher morning caloric load promotes weight loss.

Finally, although the evidence is very limited, the studies carried out in relation to the chronotype of the subjects suggest that whatever the chronotype of each subject, an early meal schedule is the best option for anthropometric improvements. However, more studies are still needed to complement and confirm the current evidence, as it is still limited and scarce.

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*Efecto que tienen la frecuencia y horarios de las ingestas  
sobre el sobrepeso y obesidad*