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Obesity and sugar; allies or enemies

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Abstract

In the last three decades, the prevalence of obesity in developed countries has reached epidemic proportions, and continues rising. Many factors have influence on the incidence of obesity, and with the decline of physical activity, overeating plays a role in the emergence of this public health problem. Although a clear relationship between fat intake and weight gain has been established, the role of carbohydrates and more specifically from sucrose and the development of obesity is more controversial. Much of this controversy is due to the growing demand for sweetened drinks and caloric increase posed by these in the diet. Despite multiple studies and communications on this subject in recent years, there are still many areas of uncertainty about the role played by diets rich in sugars over the increase in obesity in last years.

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Key words: *Obesity. Sugar. Sucrose.*

OBESIDAD Y AZUCAR; ALIADOS O ENEMIGOS

Resumen

En las últimas tres décadas, la prevalencia de obesidad en los países desarrollados ha alcanzado dimensiones epidémicas y continua en aumento [1]. Existen múltiples factores que influyen en la incidencia de obesidad, y junto con el descenso de actividad física ,el exceso de ingesta, juega un papel preponderante en la aparición de este problema de salud pública [2]. Aunque existe una clara relación entre la ingesta de grasas y la ganancia de peso, el papel de los carbohidratos y más concretamente el de la sacarosa en el desarrollo de obesidad es más controvertido. Gran parte de esta controversia se debe a la creciente demanda de bebidas azucaradas y al posible incremento calórico en la dieta asociado a su consumo. A pesar de la publicación de múltiples estudios y comunicaciones a este respecto en los últimos años, siguen existiendo numerosas incógnitas acerca del papel que juegan las dietas ricas en azúcares en el incremento de incidencia y prevalencia de obesidad en los últimos años.

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Palabras clave: *Obesidad. Azúcar. Sacarosa.*

Abbreviations

DXA: Dual-energy x-ray absorptiometry.
GI: Glycaemic Index.
BMI: Body Mass Index.
NHANES: National Health & Nutrition Survey.
USDA: US Department of Agriculture.
FDA: Food and Drug Administration.
WHI: Waist Hip Index.

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Introduction

Obesity

Obesity is defined as an excess of fat which, generally means a weight increase. However, we can find obesity without excess weight (normal weight obesity) and excess weight without an excess of body fat.

Therefore, for a correct obesity diagnostic it is necessary to quantify the total excess of body fat. The method that is considered as the "gold standard" for evaluating the composition of the body is by dual energy x-ray absorptiometry (DXA), a technique that quantifies total body fat via a calculation of the attenuation of rays of differing intensity, which pass through the patient's body. However, the reduced availability, high cost and exposure to DXA x rays determine the major limitations of its systematic use in regular clinical practices, meaning it is used mainly for investigative studies. In this sense, the body mass index, obtained via the (kg)/size (m^2) weight formula is prob-

ably the most universally accepted indicator for the definition of obesity, given its simplicity and its strong correlation with total adiposity. The body mass index (BMI) is a universal figure, which does not take into account the sex, or different ethnic groups in percentages of body fat. For this reason, obesity in Japan, is defined by BMI ≥25kg/m^2, in China as ≥28 kg/m^2, while in Caucasians, as is our case, a BMI of between 25-30kg/m^2 is considered as overweight.

Obesity can be classified in function of the differing BMI intervals, but also by the increase in the risk of mortality, by anatomical phenotypes or etiological criteria.

According to the World Health Organization (WHO), obesity is classified as class I for a BMI of between 30 and 34.9 kg/m^2, class II for a BMI between 35 and 39.9 kg/m^2, and class III for a BMI≥40kg/m^2[3]. At the same time, class I obesity is associated with a "moderate risk", class II with a "high risk" and class III as "very high risk" of mortality. The most common anatomic characterisation refers to the predominant localisation of excess fat both at a visceral level or subcutaneous tissue level. The relationship between waist / hip size known as the WHI (waist hip index), has been used for years to identify those subjects with a central level fat excess, which means, visceral, against peripheral obesity (i.e. subcutaneous). A WHI in men > 1.0 and 0.85 in women, indicates an excess of abdominal fat. In recent years however, the WHI has not been used as it was found to be more cumbersome and the waist measurement has taken its place due to the high correlation with abdominal fat and with the loss of health. As a matter of fact the SEEDO considers the determination of waist index in the obesity classification as it has been demonstrated that, within the same BMI, a risk waist (> 102cm in men and > 88cm in women) the morbidity and mortality associated with that BMI increases. It is known that visceral adiposity is correlated with a higher probability of developing the metabolic and cardiovascular complications classically associated with obesity, while subcutaneous fat, seems to be much more benign, and in some cases it even acts as protection against the development of metabolic complications.

From an etiological viewpoint, obesity can be classified as either primary or secondary. Obesity can in fact be iatrogenic, which is to say, secondary to pharmacological treatments, including some anti-psychotic, antidepressant, antiepileptic drugs and some steroids. Certain obesity phenotypes are characteristics of some pathologies, including polycystic ovary syndrome, Cushing syndrome, hypothyroidism, hypothalamus defects and growth hormone deficiency.

Alternatively, as a primary disorder, the etiology is quite complex to analyse. Even though its pathogenesis can be expressed in relatively simple thermodynamic terms, which is to say, the excessive storage of body fat as a result of a chronic positive energy balance (i.e. excess of ingestion compared to use), the identification of the main causes of chronic energy imbalance continues to be a challenge as well as the fact that metabolic phenotypes, psychological and behaviour patterns that lead to obesity continue to be controversial. As a matter of fact, the excessive consumption of energy (or hyperphagia) is considered a characteristic highly prevalent in obese subjects. However, the connection of hyperphagia to the increase of real weight has turned out to be exceptionally difficult to document, very probably due to the fact that the measurement of energy consumption in the individuals already accounts for a real challenge, especially in obese people that tend to underestimate their food intake. Other aspects of food intake and their relationship with obesity, such as the diet make-up, the food's energy density, and the food intake figure, flavour preferences, life style and possible sub-phenotypes, have also been explored with somewhat contradictory results.

It is not surprising, therefore, that obesity related molecular biology is only partially understood. This is probably due to the heterogeneity of obesity and the fact that this is related to, the same as other complex illnesses, not by one single genetic mutation but by multiple allelic defects, which determine a higher susceptibility to environmental factors.

Despite obesity affecting a large proportion of the world's population, the incidence and prevalence estimates are not available for all countries, and the data available is not exact. In the United States the National Health and Nutrition Examination Survey (NHANES) in the last 50 years has provided data on the continual monitoring of the prevalence and incidence of obesity in a representative sample on a national level. This data shows the prevalence of obesity amongst adults (age ≥ 20 years), which started to increase notably after 1980. In 2007-08 (the set of most recent data available) obesity reached prevalence by age of 33.8% in total, corresponding to 32.2% in men and 35.5% in women. The highest prevalence is currently observed in black non-Hispanic race, followed by Hispanics and non-white Hispanics. Addressing the severity of obesity, grade 2 obesity has a global prevalence of 14.3%, while grade 3 reaches 5.7%. The racial distribution continues the same pattern as general obesity, except for grade 3, which is as frequent in Hispanics (5.5%) as amongst non white Hispanics (5.2%) (Fig. 1).

Amongst children and teenagers (age < 20 years), according to NHANES data of 2007-08, obesity reached a prevalence of 9.5% in girls and boys 0-2 years of age, while the prevalence for children from 2-19 years of age was 16.9% in both sexes. The prevalence of obesity in children by race / ethnicity is highest amongst Hispanics (12.5% for 0-2 years of age and 20.9% for 2-19 years of age), followed by black non Hispanics (10,3% for 0-2 years of age and 20.0% for 2-19 years of age), and white non Hispanic (8.7% of 0-2 years of age and 15.3% for 2-19 years of age)[4].

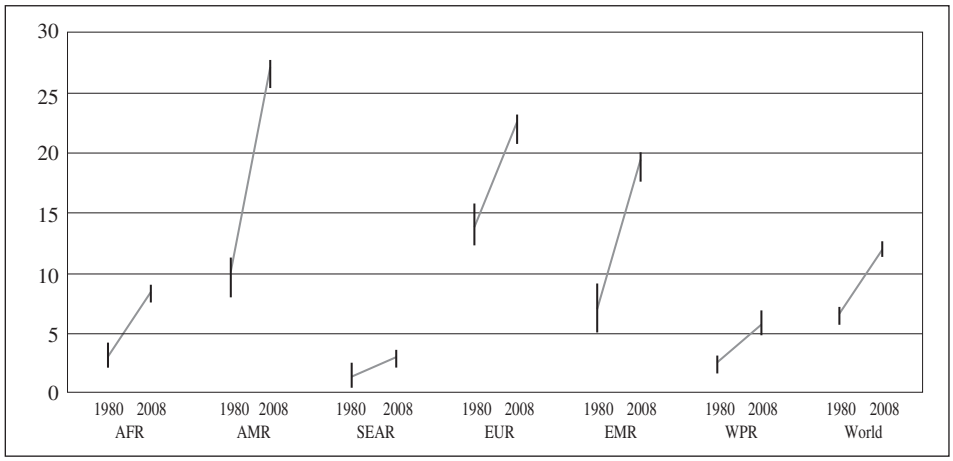

Fig. 1.—Prevalence of obesity data in the United States of America.

In the last 25 years obesity has also increased in Spain from 7% to 17% (Fig. 2). In Spain two of three men are overweight and one in six is obese.

The latest statistics show that this condition affects 10-27% of men and 38% of women in Europe. It is calculated that more tan 200 million adults throughout the European Union could be overweight or are obese. More than half the population of Spain (over 18 years of age) is above what is considered a normal weight. 45.5% of men and 29.9% of women are overweight, while 17.3% of men and 14.7% of women are obese. 52.1% of males and 43.6% of females from 65 to 74 years of age are overweight while 23.9% of men and 27.4% of women suffer from obesity.

As for the juvenile population, the percentage of childhood obesity has increased by 35% in the last decade in our country.

According to the latest figures, 21.8% of Spanish children are overweight and an 8.2% are obese, and nearly one in three children between the ages of 3 and 12 years are overweight.

Spain is the second country in the European Union, after Malta, with the highest percentage of obese or overweight children between 7 and 11 years old. Obesity has become an epidemic that every year affects 400,000 more children in Europe. 9% of Spanish school children suffer from obesity and 33% are overweight, compared to lower figures of 20% in France, Poland, Germany or Holland (Fig. 3).

As a consequence of the relationship between the excess of body fat and higher morbidity and mortality, and the rising epidemic of obesity, a high percentage of the population on a world level shows an increased risk of contracting certain illnesses and a higher risk of death by any cause[5]. In developed countries the increase of mortality associated with excessive body fat is 30-40% for coronary cardiac diseases, colon, breast and endome-

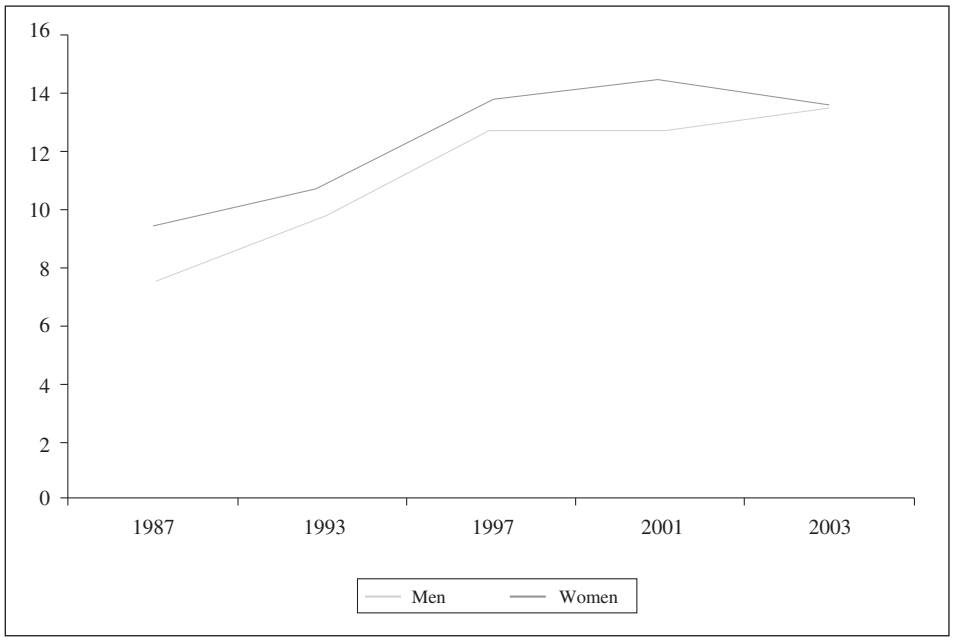

Fig. 2. —Prevalence of obesity in Spain from1998 to 2003.

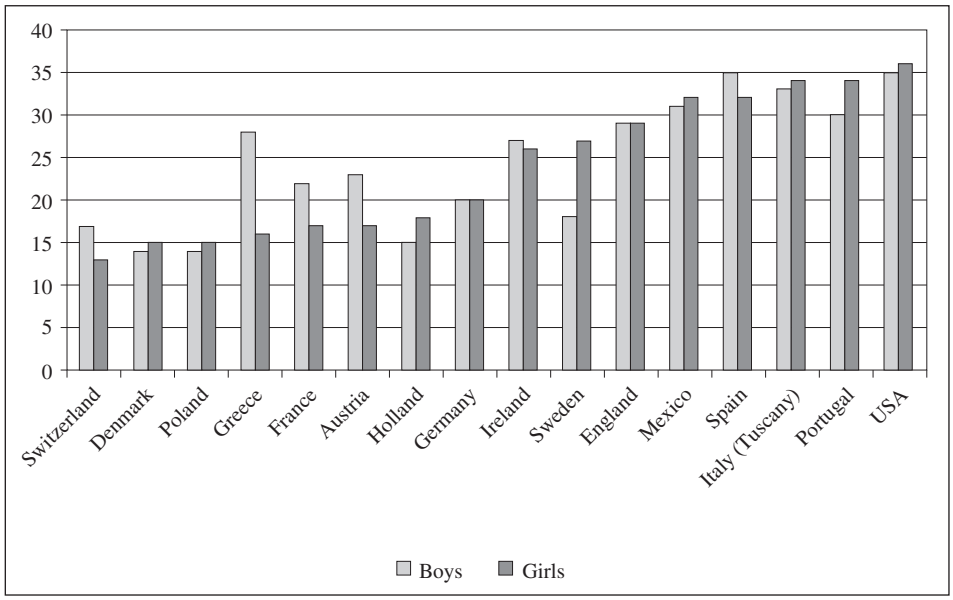

Fig. 3. —Prevalence of child obesity in European Union countries.

trial cancer, and in the majority of type 2 diabetes cases.

Even though the risks of morbidity and mortality are higher in obese people, the relationship with BMI, in terms of the range of obesity is not necessarily uniform for the illness (for example, cancer) subtypes of the genre, or race / ethnicity. In some cases, the data does not support a higher risk in obese people. For hip fractures, the observed risk was lower for body mass indexes in the region of 30 kg/m^2. In a similar fashion, the results of morbidity and mortality for obese patients with chronic renal illnesses during haemodialysis treatment, with cardiac insufficiency or peripheral arterial illnesses, seem to be better in obese patients than in those patients with a normal weight and especially in elderly patients over 75 years old. These observations have generated what is known as the "obesity survival paradox" According to some authors this paradoxis explained by the fact that patients lose weight as the underlying illness progresses. Alternatively, this paradox has recently been proposed as a plausible explanation for two well established epidemiological observations: the shape of U (concave) of the relationship between BMI and the rate of mortality, as a result that people with an intermediate BMI (25-30 kg/m^2) tend to live longer than people with a lower or higher BMI and the nadir of these curves tend to increase with age.

Sugar

With the term "sugars" we are referring to a group of compounds constituted by carbon, hydrogen and oxygen atoms that are classified in function of their chemical structure in monosaccharides, disaccharides and oligosaccharides. The monosaccharides contain 3- 7 carbon atoms per monomer, which can be absorbed by sugars. Glucose, fructose and galactose are the essential monosaccharides for the human diet, while mannose carries out a less important role. Disaccharides are compounds formed by two conjoined monosaccharides (2 monomers). Primary disaccharides in the human diet are sucrose (one glucose molecule and one fructose molecule), lactose (galactose and glucose) and trehalose (2 glucose molecules). Human beings possess enzymes which breakdown the disaccharide's links for their later absorption and metabolism in the form of monosaccharides.

Sugars provide energy and a pleasant taste; this way, the ingestion of sugars seems to be influenced by two different brain systems: those associated with the regulation of food and the energy homeostasis, and those which are associated with the reward. During the last three decades, the existence of a series of neuromodulators which can act both as an orexigene and anorexegene involved both in the regulation of energy and in the circuits that measure their reward has been widely accepted.

In terms of sugar consumption, in Spain estimations rise up to 29 kg per capita annually. This consumption can be considered relatively high, if we compare with the world consumption per capita of 21 kg, with the geographical regions of Canary Islands, Galicia and Castilla y Leon showing a higher consumption. In global terms, Spain has a consumption of about 1,300,000 tonnes of sugar per year.

Obesity and sugar

The prevalence overweight and obesity has increased considerably throughout the world in the last three decades, and, although the genetic factors seem to

play an important role in the development of obesity, the dramatic increase in the incidences of obesity seems to suggest that the environmental factors and lifestyle changes could be contributing in an important way to the epidemic tendency of this condition. Both the reduction of physical activity and the increase in consumption of high calorie foods are factors that have been directly related to the development of excess weight and obesity. Currently, the role of sugar intake, and more precisely of sucrose, in the development of obesity is raising quite a lot of interest in the world scientific community.

Unlike what happens with the ingestion of fats, for which a high correlation between the excessive consumption of them and the increase in developing excess weight and/or obesity has been proved. The relationship between the consumption of sugars included in food or added to them and the increase in weight is not so evident. Different cross-sectional studies have concluded that there is no association or even a negative association between the consumption of sugars and weight gain. However, there does exists an ample debate regarding the possibility of the higher consumption of sugar through sugary drinks producing a more significant effect on BMI. In this regard, some authors support the hypothesis that drinks do not provide the same level of satiety as solid food and therefore, consumers do not adjust correctly their total intake to compensate for the extra energy consumed through sugary drinks.

DAFO analysis regarding the relationship between obesity and sugar

Weaknesses

• Human beings present an innate preference towards sugar, due to the fact that when in the uterus, the foetus is bathed in a "sweet liquid" and, later, from birth, children feed from milk, either maternal or artificial, which contains a high sugar content, so it is not surprising to find that in adult life there is a predominant preference for sugary foods[5].

• Given that sugar is added frequently to food, the interpretations and discussions that surround the intake of sugar are complex due in great part to the large number of terms used to describe these ingredients, the lack of comparable data for the consumption of sugar in the diet, the lack of real data in the food composition databases and the almost exclusive provision of epidemiological studies as the principal knowledge base, with the limitations that this carries.

• As a matter of fact, when it comes to establishing a relationship between obesity and the consumption of sugar, one of the obstacles that we face is the difficulty to quantify precisely the quantity of sugar consumed by the population for various motives[5]:

– Even though an agreement exists regarding the chemical definitions of the different sugars, the terms sugar, sugars, added sugar, and caloric sweeteners are used without distinction in many sugar consumption studies, something which generates a great deal of confusion when it comes to establishing consumption statistics.
– When it comes to quantifying the daily sugar consumption, individuals tend take into account only added sugar, such as sucrose (white and brown sugar), saccharine, aspartame and other substitutes, excluding added sugar as an ingredient in processed or pre-prepared foods.
– Individuals tend to selectively reflect a lower intake of foods rich in fat, carbohydrates and sugar.

Threats

• The composition of the denominated "low fat" food reduces the fat content at the price of increasing principally the sugar content. Despite the popularity and increase in consumption of this type of food, the incidence of obesity keeps rising, which would explain in part the increase in obesity.

• The excess of carbohydrates in the diet with respect to the caloric requirements of each individual, not through the conversion of surplus carbohydrates into fat but through lipogenesis, again, can produce an accumulation of body fat. There is a higher priority in the oxidisation of carbohydrates against fat, but in the long term, this can result in a suppression of the oxidisation of fat with the subsequent bodily deposits maintenance.

• Foods rich in high GI carbohydrates produce abrupt peaks in hypoglycaemia followed by the proportionate liberation of insulin, a situation which promotes the postprandial oxidisation of the carbohydrate at the expense of the fat oxidisation, inhibiting the lipolysis with the consequent reduction of the quantity of free chain fatty acids and the fat oxidisation, all of which leads to an increase of body fat. Even though sucrose has a medium GI, some foods that contain it, such as breakfast cereals, sweets or pastries, tend to have an elevated GI and glycaemic load.

• The combination of frequent consumption of sugary drinks and the decrease in physical activity, is converted into a lowering of the metabolic demand for fat as an energy source, considerably increasing the risk of weight gain, especially among the younger population.

• When we compare diets with a high sucrose content with diets with a high polysaccharide content, an increase in total ingested calories of sucrose against polysaccharides in the region of 12% has been observed, which could explain the increase in consumption of sucrose in the form of sugary drinks.

• In studies that have compared the caloric ingestion and the increase in weight amongst subjects that consumed drinks sweetened with sucrose compared to others that drank drinks with artificial sweeteners, an increase of both calories consumed and the weight of those that drank drinks with sucrose, against those that drank drinks with artificial sweeteners[6].

Strengths

• Sugar, apart from the sweet taste, brings a wide variety of favourable qualities to food, such as their antimicrobial action, taste, aroma and texture, as well as viscosity and consistency, which are generated endlessly. Even though the feeling of being full is higher for proteins than for sugars, and carbohydrates is higher than that of fats, which at the same time is the major source of calories in the diet[7].

• The consumption of high fat diets produces a lowering in the intake of sugars and vice versa, a phenomenon known as the fat-sugar balance.

• In a cross-sectional study carried out on the population of New Zealand, it was observed that adults, who were overweight or obese, did not show a higher intake of sugar than people of a normal weight. Furthermore, obese children consumed less sugar than both children of a normal weight and overweight children.

• The intake of both sugars (both contained in foods and added) is not associated with the BMI.

• Studies regarding thermogenesis induced by food have shown that energy dissipated in the form of heat is lower after the intake of fat (≈7%), than after the intake of carbohydrates (≈12%) and proteins (≈22%). Furthermore, isotopic studies have confirmed the significant absence of hepatic lipogenesis again in diets with high carbohydrate content.

Opportunities

• The US Department of Agriculture (USDA) and the FDA which establish the regulation of foodstuff and food ingredients, describe the different terms to name the different types of sugar (Table I). This proposal will allow in the future a higher rate of precision when quantifying the consumption of different types of sugars, in future research projects.

• The glycaemic index (GI) is a foodstuff classification based on the postprandial response of blood glucose, compared with a foodstuff with a (glycaemic index = 100) reference. Various studies have concluded that carbohydrates, with a high GI, increase satiety in the short term compared to carbohydrates with a lower GI. Sucrose shows an average GI of (≈ 65), which generates a higher level of satiety than other sugars such as fructose with a lower GI.

• In the CARMEN study (Carbohydrate Ratio Management in European National diets) the effect on bodyweight and lipid profile of isocaloric diets with a high sugar and polysaccharide content against diets with a high fat content were compared for a period of 6 months. The results showed that diets with a high content of both sugars and polysaccharides accompanied by a significant drop in body weight from between 1.6 kg and 2.4 kg respectively in comparison to isocaloric diets with a higher fat content level.[8]

• In an important number of epidemiological studies, an inverse relationship between the intake of sucrose and body weight or body mass index, as well as the intake of sucrose and total fat intake has been observed.

• There is little evidence to prove that the different sugars or carbohydrates have a negative effect on the control of body weight.

• In studies carried out in different countries such as Australia and the United Kingdom, despite the increase

Table I
Terms and definitions of sugars according to the USDA and the FDA

Terms	*Definition*
Added sugar	Consumed separately or used as ingredients in processed or pre-prepared foods (such as white sugar, brown sugar, raw sugar, corn syrup, solid corn syrup with high fructose corn syrup, malt syrup, maple syrup, syrup, fructose sweetener, liquid fructose, honey, molasses, anhydrous dextrose, dextrose and crystal. Can contain oligosaccharides.
Sugars	All monosaccharides and disaccharides (including natural sugars and sugars added to food or drink, such as sucrose, fructose, maltose, lactose, honey, syrup, corn syrup, syrup with a high content of corn fructose, molasses and concentrates fruit juice.) Oligosaccharides are not taken into account.
Sugar	Indicates sucrose on the list of declared ingredients.
Caloric sweeteners	Sweeteners consumed directly and as foodstuff ingredients, such as sucrose (refined sugar cane and beet) honey, dextrose, edible syrups and corn sweeteners (mainly corn syrup with a high fructose content). Contains oligosaccharides.

in the consumption of caloric drinks, with artificial sweeteners, in detriment to sugary drinks, either with sucrose, fructose or syrup with high fructose content, a lowering of the incidence or prevalence of obesity has not been observed. This phenomenon is known as the "Australian paradox" and suggests that there is no association between the consumption of sugar and the appearance of obesity in the population.[9]

• Glucose is stored in the liver and muscles in the form of glycogen. Excess glucose that is not used as an immediate source of energy or for the synthesis of glycogen can be converted through lipogenesis into fat again which is stored in the adipocytes. However, this is a costly conversion in terms of energy. Astrup and Raben calculated that 68% more energy is needed (155 in comparison to 42 MJ/kg) in order to increase body fat by 1kg through carbohydrates, an therefore "it is difficult to increase fat mass in subjects of a normal body weight, particularly through carbohydrate overeating"[10].

Conclusions

• Current data suggests that, against what occurs with other macronutrients, in the case of carbohydrates, and more precisely, sugars, there is a lack of preciseness in the measurement, intake and availability. Due to this lack of clarity, the relative arguments over the health effects of sugar should be analysed carefully and always backed up by scientific evidence.

• There is little evidence to show that the different sugars or carbohydrates have negative effects on the control of body weight.

• The consumption of sugary drinks by itself does not seem to be related to the increase of the incidence of obesity in the population of the developed countries.

• In the short term, for the majority of individuals, the excess energy that comes from sugary drinks can be compensated by a reduction in the intake of successive meals. In the long term, the changes in body weight implicate physiological adaptations such as the sensation of hunger and of the metabolic rate, which tends to restore weight. Therefore, there is no clear evidence to show that the consumption of sugary drinks increases *per se* the caloric intake and causes obesity.

• Alternatively, the combination of the frequent consumption of sugary drinks together with a decrease in physical activity brings an increase in the risk of weight gain.

• Even though the quantity of calories provided by the different macronutrients is not the same (carbohydrates 4 kcal/g; proteins 4 kcal/g and fats 9 kcal/g), from an energy stand point, the number of calories ingested by an individual is independent of where it came from, and it is fundamental in the maintenance of an adequate state of good health, to maintain a balance between the different macronutrients, as changing the distribution of these macronutrients that we all accept as healthy carries a risk of not maintaining a normal body weight.

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