Effect of glycemic index on satiety and body weight

Efeito do índice glicêmico na saciedade e no peso corporal

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A B S T R A C T

Despite extensive study, the practical significance of the glycemic index of food is still debatable. The purpose of this review paper was to evaluate the effect of glycemic index on food intake and body weight based on the analysis of published studies about this topic. According to some authors, ingestion of high glycemic index diets tends to enhance appetite and promote positive energy balance. The increase of appetite associated with the ingestion of these diets is attributed to an especially sharp early post-prandial rise of blood glucose followed by a marked release of insulin and subsequent rebound relative hypoglycemia and low levels of blood fatty acids, suggesting the difficulty that the body has to access its stored metabolic fuels. Short-term investigations have generally demonstrated that ingestion of low glycemic index foods results in greater satiety and lower energy intake than high glycemic index foods. However, less is known about the importance of glycemic index to energy balance and weight control associated with chronic ingestion of foods differing in glycemic index. Carefully designed long-term studies are required to assess the efficacy of glycemic index in the treatment and prevention of obesity in humans.

Indexing terms: glycemic index; eating; body weight; satiety.

R E S U M O

Apesar de vários estudos, o significado prático do índice glicêmico dos alimentos ainda é bastante discutível. O objetivo deste artigo de revisão foi avaliar o efeito do índice glicêmico na ingestão alimentar e no peso corporal, baseado na análise de estudos publicados sobre este tópico. De acordo com alguns autores, a ingestão de dietas de alto índice glicêmico tende a estimular o apetite e promover o balanço energético positivo. O aumento do apetite, associado à ingestão de tais dietas, é atribuído à elevação aguda da glicemia pós-prandial, seguida por um aumento marcante da secreção insulínica e por uma subseqüente hipoglicemia de rebote e por baixos níveis de ácidos graxos no sangue, indicando que o organismo está tendo dificuldades para

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acessar suas reservas metabólicas. Em geral, estudos de curta duração têm demonstrado que a ingestão de alimentos de baixo índice glicêmico resulta em maior saciedade e menor ingestão alimentar do que a de alimentos de alto índice glicêmico. No entanto, pouco se sabe a respeito da importância do índice glicêmico no balanço energético e no controle de peso corporal, associado à ingestão crônica de alimentos de alto ou baixo índice glicêmico. A condução de estudos bem delineados e de maior tempo de duração se faz necessária, para avaliar a eficácia do índice glicêmico no tratamento e na prevenção da obesidade em humanos.

Termos de indexação*: índice glicêmico; ingestão de alimentos; peso corporal; saciedade.*

INTRODUCTION

Obesity represents one of the major health problems worldwide. Although the health consequences and economic costs of obesity are enormous, there is currently no effective dietary treatment for this problem. Theoretically, obesity treatment seems to be an easy task, requiring the achievement of a negative energy balance by a reduction in energy intake to meet the overweight person´s caloric needs, in practice, this is rarely achieved in a long term basis. It has been observed that the ingestion of hypocaloric diets results in the activation of homeostatic mechanisms, leading to an increase in hunger and a decrease in basal metabolic rate[1].

Alternatively, reduced energy intake leading to weight loss could be achieved by ingestion of foods leading to high satiety. An inverse relationship has been verified between the glycemic index (GI) and satiety in several[2], but not all studies[3]. Therefore, GI has been viewed by some researchers as a possible tool to be used in the control of obesity.

The glycemic index is a ranking of carbohydrate-containing foods based on the blood glucose response they elicit. It is usually defined as the area under the glycemic response curve, after consumption of 50 g of available carbohydrate from a test food. The GI values are expressed relative to the glycemic response observed after the ingestion by the same subject of the same amount of a reference food, which can either be glucose or white bread[4]. The glycemic load (GL) is the product of a food´s GI and the amount of carbohydrate consumed in a meal, divided by 100[5]. Therefore, the main difference between these two parameters refers to the fact that the glycemic response is evaluated after the ingestion of a fixed (GI) or a non-fixed (GL) amount of carbohydrates available in a meal.

In general, high GI foods contain high refined carbohydrate content and are rapidly digested. Other factors that may favor the increase in GI include high glucose or starch or sucrose content relative to lactose and fructose content (lactose yields less glucose, and fructose does not increase blood glucose), low soluble fiber content (soluble fiber forms a gel in the stomach, reduces the rate of gastric emptying and therefore the rate of digestion and absorption); and finally soft, overcooked or highly processed foods (intact grains and discrete harder pieces of food are digested at a slower rate than those types of foods)[6].

The purpose of this review was to evaluate the effect of GI on satiety and body weight control based on the analysis of published studies about this topic.

Glycemic index and satiety

It has been claimed that high GI diets have an inferior satiating power compared to low GI diets[7]. Therefore, ingestion of low GI foods may play a role in preventing and treating diabetes[6] and cardiovascular disease[8] by affecting the risk for obesity. In a crossover study, after an overnight fast, subjects received high, medium or low GI test meals having similar macronutrient composition, fiber content and palatability. Higher hunger rating and energy consumption 5 hours later was verified after the ingestion of high GI test meals[2].

A study suggests that low GI foods result in slow, prolonged glucose disposal following a meal, producing greater satiety than foods with high glycemic and insulin responses[7]. However, there were differences in the macronutrient composition, energy density and weight of the high and low GI preloads tested, thus confounding the outcomes. In another study, high GI (glucose drink or potatoes) or low GI (barley) or non-energy placebo drink were ingested by 10 men and 10 women after an overnight fast. Despite the fact that the test foods presented different GI values, this difference did not predict their effects on satiety or food intake[9]. The results of this study do not support the hypothesis that lower GI foods lead to greater satiety and less food intake than higher GI foods. However, foods tested in that study[9] differed in weight, volume, energy density, macronutrient composition and fiber content. To study the effect of GI *per se*, all these dietary factors should be kept constant[10].

Although Holt & Miller[11] verified that food intake was inversely related to the glycemic and insulinemic responses, 2 hours after ingestion of preloads differing in GI, when those calories were added to the number of calories ingested for the rest of the day, no difference in total intake was noted. On the other hand, a study conducted by Stewart et al.[12] showed that there was no difference in subjective measures of appetite or intake 30 and 120 minutes after ingestion of two cereal treatments containing fructose or glucose added to milk. However, when food intake at 30 and 120 minutes was plotted as a function of time, a steeper slope was obtained for the glucose treatment, compared with the fructose treatment. This result indicates that glucose, which has a higher GI than fructose, may have a weaker suppressive effect on food intake with passage of time. The results of these two last studies[11, 12] clearly demonstrate that further investigation is needed to evaluate the effect of GI on food intake for a longer period of time.

In another study[13] low GI foods resulted in higher satiety scores. However, the foods tested differed in palatability. A previous study[14] indicated that less palatable foods result in higher satiety scores. But, in a study conducted by Sawaya et al.[15], ingestion of solid palatable *versus* control foods resulted in higher circulating glucose, higher post-prandial respiratory quotient, and increased carbohydrate oxidation. An increase in circulating glucose following consumption of palatable foods effectively means that the foods had a higher GI and, therefore, may affect food intake. However, Teff & Engelman[16] found no difference in post--prandial blood glucose responses to palatable vs. unpalatable test foods.

Contrary to all these studies, Anderson et al.[3] verified lower subjective appetite and lower food intake 60 minutes after ingestion of high GI beverages. According to those authors, the rapid increase in blood glucose after the ingestion of rapidly digestible, high GI carbohydrates may increase satiety in the short-term, whereas the consumption of slowly digestible, low GI carbohydrates resulting in slow, prolonged glucose disposal may be more effective in sustaining satiety in the long term[3].

In a randomized, parallel design study, a total of 72 type 2 diabetic patients ingested low GI or high GI breakfast foods. After 6 months, no significant difference in total energy intake was verified according to the study treatment. Nevertheless, participants' energy intake during the study was evaluated through the analysis of 3-day food records[17]. Some investigators have pointed out that, due to under-reporting, food records may not always predict actual energy intake[18].

In another study, the effects of consuming high or low GL meals matched for macronutrient composition, palatability and rheology of test foods were evaluated. Following confirmation of the glycemic response to each of the 48 test foods in a pilot study, 39 healthy adults consumed only those foods eliciting low or high glycemic response *ad libitum* in the laboratory for 8 days. Appetitive ratings and food intake were comparable when consuming high or low GL meals[26]. These results indicate that the differential glycemic response of the foods tested in isolation under a fixed time is not preserved under conditions of chronic, *ad libitum* consumption of mixed meals.

Glycemic index and body weight

Some studies indicate that, following ingestion of high GI meals, there is a rapid increase in blood glucose and insulin concentrations, shifting the metabolism towards an anabolic state[20], favoring weight gain. A study evaluated the effect of low GI diet compared with a standard low fat diet in a weight loss outpatient treatment program of 107 obese children. Body mass index was significantly lower for the low GI group. However, due to differences in the macronutrient composition of these two diets tested, and due to the fact that the low GI group was more exposed to positive reinforcements to meet their nutritional or physical activity goal, the effects observed in this study cannot be attributed only to GI[6].

In a randomized parallel-design study, 39 overweight or obese adults received an energy restricted diet, either low GI or low-fat. At the end of 4 months of study, changes in body weight and composition in both groups were very similar. Participants in the low GI group reported less hunger and a smaller decrease in resting energy expenditure, compared with the low-fat group[21]. Since the low GI diet had 10% more calories from protein than the low-fat diet, the low GI diet effect on hunger was expected. Besides being the most satiating macronutrient, dietary protein also leads to a smaller decrease in resting energy expenditure than carbohydrate and fat[22].

In a study conducted by Wolever et al.[22], overweight type 2 diabetic patients were prescribed high or low GI diets of similar composition designed to be moderately reduced in energy to induce a 0.5-1 kg weight loss per week. At the end of 6 weeks, small and similar amounts of weight were lost on both diets. On the other hand, in a cross--sectional cohort study involving type 1 diabetic patients (1458 males and 1410 females) food intake was evaluated through a 3-day dietary record. Consumption of a lower GI diet was found to predict lower waist-to-hip ratio and waist circumference in those individuals[23].

When obese subjects were submitted to low GI energy restricted diets for 12 weeks, significantly more weight was lost compared with a conventional balanced energy restricted diet for the same period of time. The lower insulin secretion verified after the ingestion of low GI diets may lead to a greater weight loss than standard diets[24]. Hyperinsulinemia observed after ingestion of high GI diets may preferentially redirect nutrients away from oxidation in the muscle and toward storage in fat. Rats pretreated with insulin show increased glucose utilization in white adipose tissue and decreased glucose utilization in muscle, which in turn are associated with increased food intake and weight gain[25].

In a study conducted by Bouche et al.[26], men submitted to a low GI diet for five weeks had a significant reduction in adiposity, compared with when they received a high GI diet. This decrease in fat mass was accompanied by a decrease in leptin, lipoprotein lipase, and hormone-sensitive lipase messanger RNA quantities in the subcutaneous abdominal adipose tissue. Although body weight did not differ significantly between the two dietary periods, lean body mass tended to increase with the low GI diet. Several mechanisms have been proposed to explain these findings: reduction in carbohydrate and increase in fat oxidation[27], reduction in adipose tissue lypogenesis[28], and reduction in lipoprotein lipase responsible for the uptake of fatty acids in adipose tissue[10].

In another study, ingestion of low GI or high GI diets for two eight consecutive day sessions did not result in significant changes in body weight, body mass index, lean body mass or fat mass. However, ingestion of low GI diet resulted in body weight reductions, body mass index and fat mass significantly different from zero[19]. Considering that such study lasted considerably less than the studies reporting differences of body weight and body fat[6,24,26], these results suggest that changes in the evaluated anthropometric parameters could have been more evident if the study had lasted longer.

The long term effects of high GI or low GI diets on body weight under free-living conditions were assessed in 2 recently published studies. In one of these studies, 48 overweight women participated in a 10-week, parallel, randomized intervention trial, when they received either high or low GI foods to replace their usual carbohydrate-rich foods. Although weight loss for the low GI diet (1.9kg) was higher than for the high GI diet (1.3kg) at the end of the study, this difference was not statistically signficant[29]. In the other study, 53 obese participants were randomly assigned to receive either a behavioral weight loss program (BWLP) or a BWLP + low GI education during 1-year. Athough at the end of the study, the BWLP + low GI education group demonstrated a signficant increase in GI knowledge and were eating lower GI diet, no signficant difference was observed for weight loss or weight regain compared with the BWLP group[30]. Even though these long-term trials provide information of greater ecological relevance, due to their reliance on free-living participants, they have limited experimental control.

CONCLUSION

The relative influence of GI of foods on satiety and, consequently, on obesity control, remains highly controversial. Although some short-term human studies suggest that low GI carbohydrates suppress hunger more effectively than high GI carbohydrates, there is currently little data on the GI effects on body weight. Long-term well-designed human studies are necessary to evaluate how high and low GI diets (containing foods of the same volume, energy density, macronutrient composition, fiber content and palatability) affect energy intake, body composition, and body weight for biologically significant periods of time.

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