

# Glycemic Properties of Carbohydrates and Relevance for Health

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**Abstract:** The increasing prevalence of overweight and obesity predicts an increase in non-communicable disease. Healthier diets can reduce this risk and diets that reduce or modify the nature of the carbohydrate content have been successful. Inclusion of pasta as a principal carbohydrate has reported to be of benefit. We reviewed the relevant published research literature on diets, carbohydrates, glycemic index, glycemic load and pasta. Dietary carbohydrates differ in their glycemic index (GI) the rate of increase in blood glucose following carbohydrate ingestion, and there is evidence that diets with lower GI and lower glycemic load (the GI multiplied by the amount of carbohydrate) may be beneficial in promoting weight loss or reducing weight gain. High fiber carbohydrates, such as whole grains, and pasta, have a relatively low GI, and observational studies and some, but not all, randomized controlled trials have reported a reduction in overweight and obesity, and a possible reduction in risk of type 2 diabetes mellitus, but not cardiovascular disease, with lower GI diets. In addition, observational studies and a trial of the Mediterranean diet that included increasing pasta, have reported that diets higher in pasta have improved weight loss. Thus, there is evidence to suggest that lower GI diets, including pasta and other low GI carbohydrates, have a potential (but not yet definitive) role in helping reduce overweight and obesity and the risk of non-communicable diseases.

**Keywords:** Dietary Carbohydrates, Glycemic Index (GI), Glycemic Load (GL), Pasta, Obesity, Non-communicable Diseases

## 1. Introduction

The increase of overweight and obesity with the concomitant risk of chronic diseases as type 2 diabetes mellitus (T2DM), hypertension and cardiovascular diseases poses considerable challenges for health of the world population, mainly in high- and middle-income countries. Obesity and overweight are the fifth worldwide risk factor for death and the third of coronary heart disease, ischemic stroke, T2DM and several types of cancer in middle-income countries [1, 2].

Overweight and obesity are defined in terms of Body Mass Index (BMI, [weight in kg/length or height in meters<sup>2</sup>]) and waist circumference [2]. The global mean BMI in adult men increased from 21.7 kg/m<sup>2</sup> in 1975 (95% CI: 21.7- 22.5) to 24.7 kg/m<sup>2</sup> (95% CI: 24.6 – 25.0), and in women 22.1 kg/m<sup>2</sup>

(95% CI: 21.7- 22.5) to 24.7 kg/m<sup>2</sup> (95% CI: 24.6 – 25.0) [3]. In Peru, the average BMI in adult man increased from 22.4 kg/m<sup>2</sup> in 1975 (95% CI: 20.2 – 24.7) to 26.4 kg/m<sup>2</sup> in 2015 (95% CI: 25.9 – 26.9) and for women from 23.5 kg/m<sup>2</sup> (95% CI: 21.3 – 25.8) to 27.3 kg/m<sup>2</sup> (95% CI: 26.8 – 27.8) during the same period [4].

Obesity, especially abdominal obesity, is often accompanied by the metabolic syndrome, characterized by at least three of the following criteria: central obesity, hypertension, elevated plasma glucose, insulin resistance and/or dyslipidemia [5]. In turn, it is associated with a low-grade chronic inflammatory state characterized by an increase of biomarkers such as C-reactive protein. A study carried out in 2006 in 4053 Peruvian adults [6] noted that the 65.6% of the analyzed population showed abdominal obesity, the 30.0% had high

triglyceride levels, the 19.1% had high blood pressure and the 54.2% had low levels of HDL cholesterol. Also, reported of a high prevalence of metabolic syndrome (25.8%), which affected 34.3% of women and 16.6% of men.

Taking into account these data, this work evaluates the possibility of reducing obesity, along with its concomitant risks, modifying the carbohydrate intake with different glycemic index (GI) and glycemic load (GL), as well as the possible role of pasta in this context.

## 2. Methods

The sections about GI, GL and pasta are based on bibliographic searches in PubMed, including the terms: “dietary carbohydrates”, “glycemic index”, “glycemic load”, “obesity”, “overweight”, “non-communicable diseases” and “pasta” as review topics. The abstracts of the relevant articles were reviewed and selected as necessary. The non-identify jobs on the search but cited in the literature were also reviewed.

## 3. Dietary Advice and Guidelines

Dietary advice and guidelines are important to educate and motivate population to consume diets associated with a healthy life and a minor risk of related diseases. Changes on diet can reduce the proinflammatory “environment”, the metabolic syndrome and the subsequent risk of developing T2DM and cardiovascular diseases. For instance, the blood levels of C-reactive protein are reduced with “healthy” diets, as the Mediterranean, Nordic and DASH diets, which typically include fruits and vegetables, whole grain carbohydrates and vegetable-based fats [7]. A review concluded that the metabolic syndrome markers were reduced in diets that result in weight loss, including low-carbohydrate diets, to a lesser extent, low-fat diets [8].

For many years, dietary advice that gone after the establishment and the maintenance of a healthy eating, as well as avoiding obesity, emphasized low-fat diets resulting in relatively higher carbohydrate diets [9]. However, higher carbohydrate diets produce insulin resistance [10], which increase the risk of developing T2DM, hypertension, metabolic syndrome and cardiovascular disease [11].

Epidemiological studies and Randomized controlled trials [12-14] supported the recommendation of low-carbohydrate diets, especially those with high protein content, to prevent overweight and obesity, and several factors for cardiovascular disease. That these relatively low-carbohydrate diets and high-fat diets produce HDL (high-density lipoprotein) was shown, while reducing adipocytokines (adiponectin and leptin), secreted by adipose cells and implicated in vascular inflammation, and biomarkers of the cardiovascular disease [14] and metabolic syndrome [8]. Examples would be the Atkins diet [15], which is characterized by being composed of 10-35% carbohydrates and 70% fat, or the Mediterranean diet [16] in which typically around 40% of calories come from the lipids provided by olive oil, 45% of the carbohydrates and the remaining 15% from proteins; both diets have proven reduce

the risk of developing cardiovascular diseases [17] and/or T2DM [18]. Other authors agree in recommend a restriction of the carbohydrate intake accompanied with a major proportion of proteins, to reduce unfavorable blood lipids, and advice low-carbohydrates diets to reduce body weight, even with the warning that excessive reduction in muscle glycogen can cause fatigue and long-term adherence to these diets maybe low [19].

An important factor is the effect of the quality and source of carbohydrates, as well as the consideration of which foods substitute them. For instance, on a longitudinal study carried out in Boston (USA), the carbohydrate substitution for foods of animal origin high in fat and protein was associated with a major risk of coronary heart disease, but if the consumption of healthy vegetable fats was increased, it resulted in a lower risk [20]. Other alternative diets, like “Nordic” diet, based on the dietary pattern of the Scandinavian countries [21, 22] recommend that more than 50% of calories come from carbohydrates sources, but focus on high dietary fiber and vegetable-based fats. Nevertheless, recent studies about low calories diets with different proportions of macronutrients indicate that different diets give equally satisfactory results, at least in short-term [23], just as that the composition of macronutrients, including the amount of carbohydrates on diets does not convincingly predict the weight gain or loss, and it does not reduce obesity [24, 25]. In such a way, in general, diets can be healthy if they do not exceed the calorie requirements, they are diverse and satisfy the micronutrients necessities. On the other hand, results of the randomized controlled trial DIETFITS, which compared a low carbohydrate diet with a low-fat diet, did not report differences in respect of weight loss after 12 months of diet [26]. However, in all dietary interventions there is considerable variability in the individual respond, and the adherence to diets is recognized as a major limitation.

## 4. Composition and Carbohydrate Sources on Diet

Although the proportion of main macronutrients losses importance, there is too much discussion about the ideal type and quantity of carbohydrate in recommended diets. Carbohydrates include simple and complex sugars and fiber; and the differences in dietary guidelines with respect to these do not stand out when they are considered generically as a “macronutrient” in the composition of the diet. It is more useful to distinguish between simple sugars, such as those in sweetened beverages universally considered as obesogenic, whereas other carbohydrates especially those from vegetable sources and those with high fiber content are considered to be beneficial [27, 28].

Simple and refined sugar, such as white bread, are associated with a pro-inflammatory effect, whereas substituting these carbohydrate sources for whole grain cereals, with a higher fiber content, has a natural anti-inflammatory effect [6] and they are linked with decrease circulating levels of free radicals and proinflammatory

cytokines [8]. Therefore, diets such as Nordic diet, which are composed of relatively high content of carbohydrates, promote the intake of whole cereals, fruits and vegetables, food with high fiber content [21].

Therefore, although nowadays dietary advices for a healthy life, lose weight and avoid metabolic syndrome, can vary in specific aspects, there is an emphasis on food with fewer refined carbohydrates and an increase in fruits, dried fruits, fiber-rich fruits, sparingly restricting total carbohydrates [29, 30]. Furthermore, universal guidelines limit the consumption of simple and added sugars, such as those in sugar-sweetened beverages that induce the postprandial hyperinsulinaemia [31, 32].

## 5. Glycemic Index (GI) and Glycemic Load (GL)

The GI is a characteristic of the carbohydrates in a specific food [39]. It is a measure of the rate and amplitude of the rise in the capillary blood glucose following ingestion of a carbohydrate compared with a predetermined carbohydrate source usually 50g of glucose or white bread. For its part, GL is the glycemic index multiplied by the amount of carbohydrate in a meal. Tables of GI values for different foods [40] can be found in the bibliography, with which GI and GL of different diets can be calculated from the frequency and quantities of different carbohydrates. Among food that are common sources of carbohydrates, white bread and potato have a relatively high GI, meanwhile pasta, such as spaghetti, has lower glycemic indexes. GL takes into account both quality and quantity of carbohydrates in the food or meal consumed [40].

In reference to GI/GL, it is important to take into account that may be a variation due to the origin of the carbohydrates and the variability in its vegetable origin. For instance, different varieties of rice have different proportions of amylose: amylopectin (starch constituents), and that the cooking methods used at the preparation of food can also cause a variation in the GI [41].

The beneficial role of a low glycemic index of the carbohydrates has been debated by expert groups since 1998, when the Food and Agriculture Organization (FAO) recommended that carbohydrates will be classified according to their potential to raise the glucose level [33]. Afterwards, in 2006 an expert's review concluded that there was not enough evidence to recommend GI as an element to take into account to reduce the obesity risk or as a measure to lose weight in obese people, despite observing a potential benefit for glycemic control in diabetes [34]. It was considered to take into account, as alternative explanation, that the potential benefits of food with low GI are due to their higher fiber and whole grain content. By the same token, they recommend conducting studies that define the potential benefit of the glycemic index, especially in processed food [34]. However, a year after, a Cochrane review concluded that, in people with overweight and obesity, diets with low GI/GL were effective for promoting weight loss and improve

the blood lipid profile [35], even though they recognized the short duration of the studies in which they were based on. Subsequently, a systematic review reported that diets with low GI/GL, independently of the fiber intake, were associated with a lower risk of suffering from chronic diseases, including T2DM and cardiovascular disease [36]. Along the same lines, another successive review concluded that diets with low GL favored the glycemic control [37]. In 2013, an expert's meeting reinforced the usefulness of GI and GL in the precaution and treatment of the T2DM, chronic heart diseases and obesity, especially in presence of insulin resistance [38].

## 6. GI/GL and Their Relationship with Non-communicable Diseases (NCD)

Observational studies have suggested that the GI on diets is important to prevent different chronic diseases, such as cardiovascular diseases [42, 43]. A meta-analysis elaborated from prospective studies that made a following to adults during 6 to 20 years (with an average duration of 11.5 years) manifested that the relative risk of suffering from a cardiovascular disease increased with increasing both GL and GI after adjusting for age, BMI, smoking and physical activity [44]. Another meta-analysis that collected data from 37 prospective cohort studies concluded that a higher GI and GL on diet was associated with a higher risk of suffering from chronic non-communicable diseases in general, specifically relating the GI with coronary heart disease [36]. In that sense, a study carried out by Halton *et al* showed that a higher GL was strongly associated with a higher risk of coronary heart disease in women [20] and another job carried out with 5830 Mexican health workers associated a diet predominantly high in GI and GL foods with an adverse lipid profile, and a higher relative risk of suffering from chronic cardiovascular disease [45].

Later, on year 2015, the Scientific Advisory Committee on Nutrition report (SCAN) [32] supported those findings relating a higher GL with a higher risk of suffering from a cardiovascular disease, even though those evidences were limited because of the small number of studies. Diets with higher GL resulted in a lower reduction of the diastolic blood pressure and lower reduction on the fasting blood triacylglycerol concentration. Nevertheless, the existence of confounders cannot be excluded, since diets with higher fiber contain have low GI and GL, and it may be that the advantages found are due to the higher fiber contain instead of lower GI or GL.

A recent trial that assessed healthy DASH diets with variations on the carbohydrate content and the GI, found no decrease of cardiovascular risk factors in relation to GI of the diet [46] and, according to other cited trials, it was concluded that there was no convincing proof of an effect of GI and GL on vascular function or inflammatory markers. Thus, there is some controversy on the obtained results for different studies about the risk of suffering from a cardiovascular disease and

the GI [47, 48], so that a definitive role cannot be given to the GI on the dietary guidelines for the prevention of cardiovascular diseases.

## 7. Diabetes Mellitus

The prevalence of T2DM, related to obesity, is also on increase [49]. The first studies carried out in this regard concluded that diets characterized by carbohydrates with low GI and GL were associated with the increase of the insulin sensitivity and a lower risk of T2DM, independent from the content of indigestible carbohydrates, such as dietary fiber. Moreover, the benefit of diets with a low GI was greater in those subjects with higher fasting blood glucose levels [50]. Afterwards, the same author carried out a bibliographic review in which concluded that there was a significantly lower risk of T2DM in people who consumed diets with a lower GL [51].

On the other hand, a trial about several healthy diets in which the carbohydrate content and GI were varied, showed that both the reduction of the amount of carbohydrates in diet and the reduction of GI generated a measured increase in glucose, avoiding high spikes in blood glucose. This in turn, kept the hemoglobin A1c in low levels, which was associated with a reduced risk of suffering T2DM, similar effect to a diet with reduced carbohydrates [46].

Thus, diet with low GI also work to improve the control of diabetes, and along with high protein diets, they improve the blood levels of markers of cardiovascular risk in diabetics [40]. Moreover, another review concluded that diets with low GL resulted in a clinically significant improvement of the diabetes management, even comparable to the obtained with specific medication [35]. Because of this, dietary guidelines for diabetics also recommend include carbohydrates with low GI on diet [52, 42].

## 8. Overweight and Obesity

A recent study conducted in an endocrinological clinic in Lima with overweight or obese children noted that more than 91% of the participant had a diet with high GL and the 22.3% metabolic syndrome. Concluding that a higher dietary GL was associated with the metabolic syndrome [53]. However, not all the epidemiological studies carried out have obtained similar findings in relation to GL. For instance, in Brazil, dietary GI and GL were not identified as risk factors for obesity [54].

A first randomized controlled trial (RCT) which compared a low-fat diet with a low GI diet in children, reported a greater weight loss over a 4-month period with the low GI diet [55]. Another RCT [56], carried out in 22 children with obesity, which measured the effect of 2 hypocaloric diet with similar macronutrient composition but different GI for 6 months, reported that in addition to a BMI significant reduction, the blood pressure and the high-sensitivity C-reactive protein levels in both groups, children that consumed the low GI diet had a lower blood triglyceride

level, a lower reduction of the waist circumference and BMI Z score. Likewise, a meta-analysis whose scope was to compare diets with different GI, reported a more prolonged reduction in fasting C-reactive protein and insulin on diets with low GI, but with no difference in the reduction of blood lipids or hemoglobin A1c. These authors concluded that diets with low GI or GL could have a role on the prevention of obesity and the development of complications [57]. In the same vein, another review of the study also showed the benefit of diets with low glycemic index in children and adolescents [58].

The SCAN consensus supports a possible role of diets with low GI and GL in the treatment of overweight, especially when there is also insulin resistance [32]. The recently proposed “Carbohydrate-Insulin” conceptual model described by Ludwig and Ebbeling suggests a quick increase in glucose and the consequent increase in blood insulin that follows the intake of high GI foods, results in a rapid deposition of calories into adipose tissue cells, which reduces blood glucose levels and calories available for oxidation of lean tissue such as muscle. Afterwards, this results in an increased feeling of hunger, appetite and eventually contributes to the weight gain and obesity [59].

The weight maintenance through the dietary advice is essential for the prevention of overweight and obesity, as shown by the results obtained on the “European Diogenes” study. In this work, participating adults were randomized to 4 different regimens of similar fiber content but varied in protein and GI for 26 weeks: 1) high protein – low GI; 2) high protein – high GI; 3) low protein – low GI; 4) low protein – high GI. It was observed that diet with high GI and low protein level was associated with weight gain, and that high protein and low GI diet, related to lower GL, was the most successful in the maintenance of weight loss. These data suggested that the high protein content contributes to reduce the weight gain by increasing satiety and, therefore, reducing overall food energy intake. In this case, the study design allowed differentiate between the role of the protein and that of the GI [60].

## 9. Dietary Sources of Carbohydrates and Their Contribution to GI, GL and Morbidity Risk

In many countries, rice is the main basic carbohydrate and several studies have found that a high consumption of this food is associated to a higher risk of suffering from T2DM, especially in Asian population (Chinese and Japanese) [61], and/or metabolic syndrome [62].

Pasta is another type of food with high carbohydrate content, which has a lower GI than white rice. Wolever *et al* [63] in a randomized study of nutritional advice in which inside of a diet with high carbohydrate level added pasta to generate a relatively low GI in patients with impaired glucose tolerance (IGT), reported a better function in pancreatic beta cells, responsible for the insulin production, which suggested that

the increase of pasta consumption instead of other carbohydrates sources could have a key role in the treatment of IGT. In line with said results, a Finnish study in which obese women and men with metabolic syndrome participated, two 12-week diets in which the main carbohydrates were, for one side, rye bread and pasta, and on the other, oat/wheat bread and potato was evaluated. The group that followed the diet based on rye bread and pasta improved in insulin secretion, which suggested that the risk of later suffering T2DM [64] could also be reduced. Likewise, another systematic review suggested a favorable postprandial effect after pasta consumption [65]. In said review, two studies showed lower generation of HbA1c and an additional study showed a lower percentage of triglycerides.

When the analysis was restricted to just the studies where pasta intake could be quantified, a statistically significant median body weight reduction of 0.7 kg was obtained. The results were similar in the long-term trials, which indicated that there was no loss of the impact of the diet over time. By the same token, the review carried out by Chiavaroli also documented possible benefits of pasta, even though these cannot be definitely attributed to this type of food [66].

These results are reinforced by the ones obtained in other studies, like, for instance, the Moli-sani study and the Italian Nutrition and Health Survey (INHES) [67]. Said study reported an association between pasta consumption and lower BMI and waist circumference. As well, a higher pasta consumption was also associated to a better adherence to the Mediterranean diet [67]. Likewise, an intervention trial in Spanish children whose scope was to promote the Mediterranean diet and increase the fruit and vegetable consumption, as well as the number of weekly pasta servings, reported that the 11.3% of children with overweight or obesity and a 2.6% of the children of the control group lost weight [68].

## 10. Conclusion

The increase in overweight and obesity and the subsequent risk of suffering from non-communicable diseases is a threat to health that affects many countries, including Peru. The advice for weight loss and health improvement needs to have a multifactorial approach, resulting essential to impulse more physical activity, such as keep a healthy diet. Since the consumption of food with low GI, which include sources of fiber, whole grains, fruits, vegetables and alternatives carbohydrates like pasta, can contribute to this scope without requiring substantial changes in local dietary preferences or habits, a possible strategy to follow would be the advice to reduce the carbohydrate consumption, particularly those with high GI. However, there are no known studies that have measured the specific impact of pasta consumption instead of other carbohydrate sources such as rice, potato or white bread. A study like that would be particularly opportune in Peru, where the consumption per capita of white rice and potato is 47.7 kg and 63.5 kg respectively [68], while pasta consumption, although is part of the regular diet, is considerably fewer (11.0 kg) [69], and where, in addition, 60% of the adult population is

overweight or obese and 25.8% has metabolic syndrome [6].

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