Glycemic impact, glycemic glucose equivalents, glycemic index, and glycemic load: definitions, distinctions, and implications[1–5]

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ABSTRACT

Glycemic impact, defined as "the weight of glucose that would induce a glycemic response equivalent to that induced by a given amount of food" (American Association of Cereal Chemists Glycemic Carbohydrate Definition Committee, 2007), expresses relative glycemic potential in grams of glycemic glucose equivalents (GGEs) per specified amount of food. Therefore, GGE behaves as a food component, and (relative) glycemic impact (RGI) is the GGE intake responsible for a glycemic response. RGI differs from glycemic index (GI) because it refers to food and depends on food intake, whereas GI refers to carbohydrate and is a unitless index value unresponsive to food intake. Glycemic load (GL) is the theoretical cumulative exposure to glycemia over a period of time and is derived from GI as GI × carbohydrate intake. Contracted to a single intake of food, GL approximates RGI but cannot be accurately expressed in terms of glucose equivalents, because GI is measured by using equal carbohydrate intakes with usually unequal responses. RGI, on the other hand, is based on relative food and reference quantities required to give equal glycemic responses and so is accurately expressed as GGE. The properties of GGE allow it to be used as a virtual food component in food labeling and in food-composition databases linked to nutrition management systems to represent the glycemic impact of foods alongside nutrient intakes. GGE can also indicate carbohydrate quality when used to compare foods in equal carbohydrate food groupings. *Am J Clin Nutr* 2008;87(suppl): 237S–43S.

KEY WORDS Glycemic impact, glycemic glucose equivalent, glycemic index, glycemic load, virtual food component, glycemic control

INTRODUCTION

It is increasingly accepted that the blood glucose response to a food is not accurately predicted by the content of available carbohydrate in the food, as measured in traditional food analysis. At the same time, the need for food values that will complement available carbohydrate values, to enable dietary control of postprandial glycemic responses, has become recognized (1).

Accordingly, in 2004 the American Association of Cereal Chemists (AACC) established an ad hoc committee on the definition of glycemic carbohydrates charged with the task of providing "a measurable definition that will enable manufacturers to communicate the glycemic response in grams per serving of food." After lengthy and stimulating discussion, the committee proposed several recommendations and definitions, including, "Glycemic impact is the weight of glucose that would induce a glycemic response equivalent to that induced by a given amount of food" (2).

This is a simple but profound definition. It has important implications for the meaning of terminology surrounding the glycemic potency of foods, for the way glycemic potency is measured, for the management of data arising from the measurements, and for ways it can be used in controlling postprandial glycemia. Although the AACC definition of glycemic impact is simple, it requires a change in thinking, from food carbohydrates to entire foods, and from static index values to intake-sensitive values, and from unit-free values to nutrient-like values that represent glycemic effects with weight units (3).

In this article, the concept of glycemic impact is explored as much as space permits. It is explained why, in light of current knowledge, glycemic impact is an advance on the current concepts of glycemic index (GI) and glycemic load (GL) for expressing the glycemic potency of foods.

GLYCEMIC IMPACT, GLYCEMIC INDEX, GLYCEMIC LOAD: DEFINITIONS

Glycemic impact, GI, and GL are all based on the currently accepted but nonetheless crude measurement of glycemic response as the incremental area under the blood glucose response curve (IAUC) for 2–3 h after consuming food, but they each express different aspect of glycemic potency:

The (relative) glycemic impact (RGI) refers to the relative tendency of a given amount of food consumed in a single intake, such as a serving, to induce a postprandial glycemic response. RGI is measured directly by determining the amount of glucose reference required to give the same glycemic response as a relevant amount of food, so the measurement is equiglycemic, and the values produced may be accurately termed glycemic glucose equivalents (GGEs).

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$$GGE/g = (IAUC_{food}/IAUC_{glucose}) \times (\text{Wt glucose/Wt food}) \times 1\text{g} \quad (1)$$

Where $IAUC_{food}/IAUC_{glucose} = 1$ (equiglycemic). Then

$$RGI = GGE/g \times \text{food weight subsequently consumed} \quad (2)$$

The GI refers to the glycemic effect of available carbohydrate in food relative to the effect of an equal amount of glucose (4), so the measurement of GI is equicarbohydrate. GI is measured indirectly because the effect of a food, not of carbohydrate per se, is measured, although the effect is attributed to carbohydrate and is calculated on a carbohydrate base. The quantity of food used in measuring GI is not necessarily a customary intake, but is one that delivers the same amount of carbohydrate (usually 50 g) as the glucose reference,

$$GI = (IAUC_{food}/IAUC_{glucose}) \times (\text{Wt glucose/Wt available carbohydrate in food}) \times 100\% \quad (3)$$

where Wt glucose/Wt available carbohydrate = 50 g/50 g = 1 (equicarbohydrate).

The GL refers to the cumulative exposure to postprandial glycemia, as a measure of insulin demand, over a specified period of time (5). It does not take into account the pattern of loading within the specified time, ie, few high–glycemic impact meals versus frequent meals of low glycemic impact. It is calculated indirectly as the product of the average GI of carbohydrate foods consumed and the total carbohydrate intake over a specified time period.

$$GL = GI/100 \times P \times \text{weight of food} \quad (4)$$

where *P* is the proportion of available carbohydrate in the food.

GL (GI × available carbohydrate) contracted to a single intake of a single food approximates but is not the same as RGI, because the GGE of a food quantity is measured from the amount of glucose reference required to induce an equal glycemic response. In contrast, when GI is measured, the food and reference are consumed to provide an equal available carbohydrate content, but seldom induce equal responses. The inequivalence of food and reference responses in GI determination may lead to large discrepancies between RGI (GGE intake) and GL if GL is calculated from GI. The differences in determination of GI, GL, and GGE are summarized in **Figure 1**.

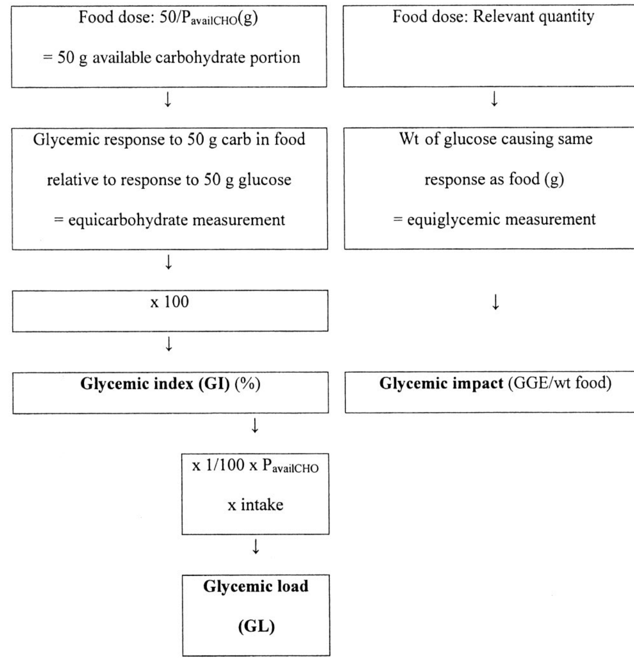

FIGURE 1. Differences between the glycemic index (GI), glycemic load (GL), and glycemic glucose equivalent (GGE) for a food. $P_{availCHO}$ is the proportion of the food that is available carbohydrate. Calculating GL from GI converts the GI value back to a food and a per gram basis. Glycemic impact is a direct measure of the relative food effect. Carb, carbohydrate; wt, weight.

THE IDEA OF GLYCEMIC IMPACT

The term *impact* has 2 meanings in English (Concise Oxford Dictionary): 1. The act of impinging (from which the word is derived). 2. A marked effect or influence. In the term *glycemic impact*, it is used in the first sense, as a food property, which is the stimulus leading to a postprandial change in blood glucose concentration, which is the response. Although the glycemic impact of a food is quantified in the first place by measuring glycemic responses to a given amount of the food and to a glucose reference, it is subsequently treated as a food value that can inform consumers of the relative glycemic potential of the food as glucose equivalents, compared with that of other foods and quantities of them. Importantly, it allows RGP to be measured as a food property independent of the modulating factors that determine highly individual glycemic responses and introduce a high degree of variability to blood response measurements.

The word *impact* has another essential implication: that the stress or load is rapidly imposed, so it is discretely related to the glycemic response that immediately follows a food intake event. In contrast, the term *load*, as in GL, is defined as "the daily carbohydrate intake multiplied by the average glycemic index," and refers to a total accumulation. The term *impact* was intentionally used by the AACC committee to communicate the fact that values refer to a single intake and its associated acute postprandial response.

THE CONCEPT OF GLYCEMIC EQUIVALENCE

Another essential facet of the definition of glycemic impact is that it is based on the concept of equivalence. Saying that glycemic impact is a weight of glucose, equivalent in effect to a given weight of food, means that it may be expressed as glucose equivalents. But because glycemia is the specific context of the equivalence, the term *glycemic glucose equivalence* is more precise. Thus, if a serving of a food has a glycemic impact equivalent to that of 15 g glucose, one may say that the food serving has a GGE content of 15 g.

There are important implications of expressing the glycemic impact of a given weight of food in terms of its glucose equivalence, related to both the use and the measurement of glycemic impact:

- The idea is easy to grasp. It means simply that "this amount of food equals that amount of glucose in its effect." The simplicity of the concept is seen visually in **Figure 2** and in **Table 1**.

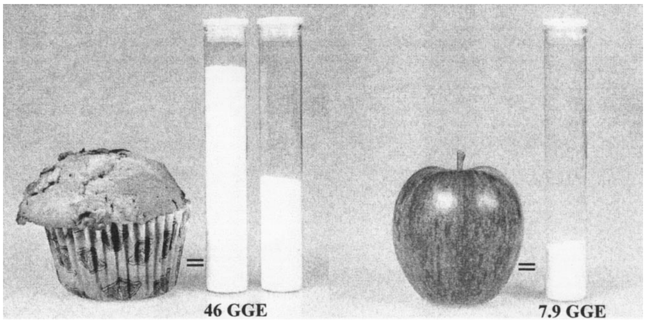

FIGURE 2. Glycemic impact expressed as a glycemic glucose equivalent (GGE) intake. The sweet muffin has a glycemic impact equivalent to that of 46 g glucose, and the apple's glycemic impact is equivalent to that of 7.9 g glucose.

- Expressed as GGE, glycemic impact values are in the same format as nutrients, with gram units (Table 1). A GGE content embodies all factors that determine the net glycemic effect of a food, expressed as the weight of glucose that would have the same effect as a given weight of the food, its RGI.
- Because glycemic impact is based on equivalence of effect, the method used to measure it should allow for determination of amounts that give an equal effect.

Food effects that can be expressed in terms of a weight of reference of known activity per unit weight are termed virtual food components. Although expressed in the same format as real food components, virtual food components represent food effects (6). The use of weight equivalents to express nutritional effects is well established in nutrition. For instance, retinol equivalents and niacin equivalents are used to express the net effect of groups of compounds. The wheat bran equivalent is a virtual food component that represents the fecal bulking effect of a food expressed as a weight of wheat bran (7).

With the enormous emphasis being placed on functional foods, there is need for a family of virtual food components that will inform food manufacturers, health professionals, and consumers of the relative efficacy of foods along several dimensions of efficacy. When the AACC Board asked for a value that would "communicate the glycemic response in grams per serving of food," they were, with great foresight, asking for a virtual food component to express glycemic impact. GGE is a virtual food component that allows glycemic impact to be expressed as grams of glucose per amount of food consumed.

APPLICATIONS OF GLYCEMIC IMPACT

Expressing glycemic impact in the form of a food component enormously extends the range of applications in glycemic control beyond those possible with GI. By being based on a virtual food component (GGE), glycemic impact can be used in the same way as most real food components to show the following:

- the likely relative glycemic effect of equal or different amounts of foods as their GGE content, in nutrient information panels (Table 1) or in food tables [**Table 2** (8)]
- the effects of changing food intakes, because GGE quantity is a direct function of food quantity
- the effects of combining foods, by summation of GGE values over a practical glycemic impact range
- the quantities of foods that may be exchanged for the same glycemic effect in food exchange tables for glycemia management (9)
- the nutrient profiles of foods or meals based on real and virtual food components combined to concurrently show nutrient intakes and food effects; these may be the output of a food-composition database interfaced with an electronic nutrition management system (10), as shown in **Figure 3**
- the effects of the RGI (GGE dose) of meals could also be interfaced with blood glucose monitoring and insulin-delivery systems to provide a dose-adjusted insulin delivery with concurrent feedback to the nutrition management system to achieve iterative meal planning in response to the changing health status of an individual.

GGE was never intended for use in isolation, but rather as a means of integrating food effects and nutrient intakes in nutritional management to provide more complete nutritional solutions than are possible with current food analytic values alone (3, 10).

METABOLIC CONSEQUENCES OF CHOOSING FOODS BY GLYCEMIC IMPACT

The metabolic consequences of using GI and RGI to manage glycemia may differ, because GI is used when foods have already been selected on the basis of their carbohydrate content, whereas

TABLE 1
Alternative presentations of glycemic impact as glycemic glucose equivalents[1]

Muesli	Per 65 g	Per 100 g
Glycemic impact external to nutrient information panel[2]		
Food components		
Energy (kJ)	1040	1600
Protein (g)	5.9	9.1
Fat (g)	5.1	7.8
Total carbohydrate (g)	46	70
Dietary fiber (g)	9.1	14
Total niacin equivalents (mg)	1.6	2.5
Food effects		
Glycemic glucose equivalents (g)	18	28
Glycemic impact per serving: medium		
Glycemic impact within nutrient information panel[3]		
Food components		
Energy (kJ)	1040	1600
Protein (g)	5.9	9.1
Fat (g)	5.1	7.8
Total carbohydrate (g)	46	70
Dietary fiber (g)	9.1	14
Total niacin equivalents (mg)	1.6	2.5
Glycemic impact		
Glycemic glucose equivalents (g)	18	28

[1] A 65-g serving of muesli has the same glycemic impact as 18 g glucose. The glycemic impact per serving falls into the medium category.

[2] Glycemic glucose equivalent as a virtual food component is included with other food components in the nutrient information panel, but supports glycemic impact as a consumer signpost external to the nutrient information panel.

[3] Glycemic impact presented within the nutrient information panel accompanied by its glycemic glucose equivalents.

TABLE 2
Presentation of glycemic glucose equivalents (GGE) in a food table[1]

Food	Common standard measure	Weight	GGE	GI	Energy	Available CHO	NSP	Total fat	SFA	Protein	Sodium	Water
		g	*g*	*%*	*kJ*	*g*	*g*	*g*	*g*	*g*	*g*	*g*
Bakery products												
Bagels, plain	1 bagel	100	29	72	936	45	2.0	1.6	0.2	7.7	492	43
		74	22	72	693	34	1.5	1.2	0.2	5.7	364	32
Biscuit, basic, NZ recipe	1 biscuit	100	16	42	1930	51	1.6	26.6	17.3	5.6	161	15
		12	2.1	42	232	6	0.2	3.2	2.1	0.7	19	2
Biscuit, flat fruit	1 biscuit	100	48	77	1390	69	2.7	4.7	2.2	4.5	177	16
		13	6.2	77	181	9	0.4	0.6	0.3	0.6	23	2
Biscuit, oatcake	1 biscuit	100	26	55	1800	57	6.1	18.3	3.9	10.0	1230	6
		15	3.8	55	270	9	0.9	2.7	0.6	1.5	185	1
Biscuit, plain, digestive	1 biscuit (0.7 × 7 cm)	100	32	59	1900	65	3.6	18.9	9.0	7.0	330	4
		13	4.2	59	247	8	0.5	2.5	1.2	0.9	43	1
Biscuit, shortbread, retail	1 biscuit (11 × 5 cm)	100	32	64	1980	60	1.9	23.9	12.2	5.5	280	4
		12.5	4.3	64	248	7	0.2	3.0	1.5	0.7	35	0
Biscuits, arrowroot	1 biscuit	100	45	69	1760	76	4.1	10.4	4.4	6.9	277	3
		8	3.5	69	141	6	0.3	0.8	0.4	0.6	22	0

[1] Based on *Tables of Glycemic Glucose Equivalents in New Zealand Foods* (8). CHO, carbohydrate; NSP, nonstarch polysaccharides; SFA, saturated fatty acids.

a low GGE intake may be achieved by the less desirable practice of replacing carbohydrate with fat (11). The apparent differences between RGI and GI do not, however, have anything to do with an intrinsic property of GI versus GGE; such an argument implies that nutrient intakes are considered when GI, but not GGE, is used. This is certainly not the case; the main purpose of GGE values is to allow concurrent management of food effects and nutrient intakes. GGE values have always been intended for use in multidimensional nutritional management.

When foods have been placed into groups of equal carbohydrate content, GGE values function in exactly the same way as GI to identify alternatives of lesser glycemic impact. Conversely, if GI is used without regard to nutrient intake or carbohydrate content by the consumer in the supermarket, where foods are not necessarily grouped by equal composition

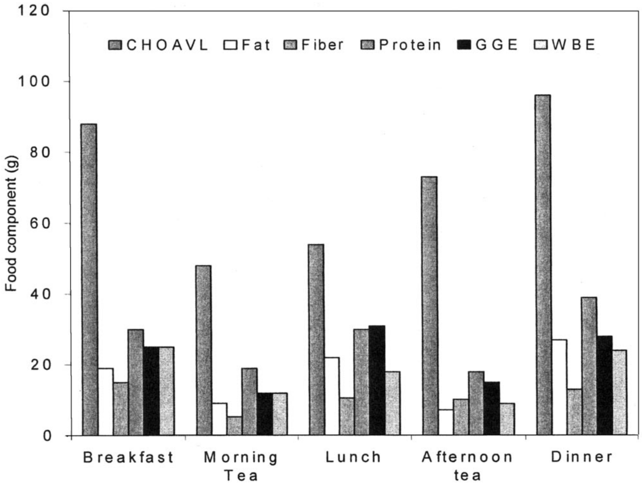

FIGURE 3. Example of a printout from a nutrition management system showing concurrent nutrient intakes and relative food effects. The virtual food components, glycemic glucose equivalents (GGE), and wheat bran equivalents (WBE) represent glycemic impact and fecal bulking potential, respectively. CHO AVL, available carbohydrate.

and serving size and where there are no constraints on freedom of choice, it may not lead to healthier or even less glycemic food choices.

METHODOLOGIC IMPLICATIONS OF GLYCEMIC IMPACT

Because the AACC definition of glycemic impact is based on glucose equivalents, and the glycemic response to glucose intake is nonlinear like most physiologic responses, important requirements exist for a procedure that will measure RGI. To directly measure true equivalence to a reference, the effects of the food and the reference need to be compared at a point of similar responsiveness on the dose-response curve. Also, the measurement should be made with a usual intake of food to minimize the inaccuracy that inevitably arises when daily food choices differ from the quantity used to measure the GGE content.

The blood glucose response has been consistently shown to be an almost quadratic function of the glucose dose (12-17), which reaches a plateau (or maximum) between 60 and 100 g glucose intake (**Figure 4**). However, in the current standard procedure for measuring the relative glycemic effects of food carbohydrates in GI determination, the glycemic response to a food portion containing 50 g of "available" carbohydrate is compared with the response to a 50-g glucose reference (18), so the comparison is equicarbohydrate, because it involves equal amounts of available carbohydrate. Consequently, if the carbohydrate in a food is significantly less glycemic than is glucose, the glycemic response to the 50-g available carbohydrate food portion may be widely separated from the response to the glucose reference on the GGE dose–glycemic response curve, and is therefore measured at a point of different glycemic responsiveness (**Figure 5**). Under such circumstances, the effect of the food cannot be directly or accurately expressed as glucose equivalents without making some allowance for the nonlinearity of the dose-response curve.

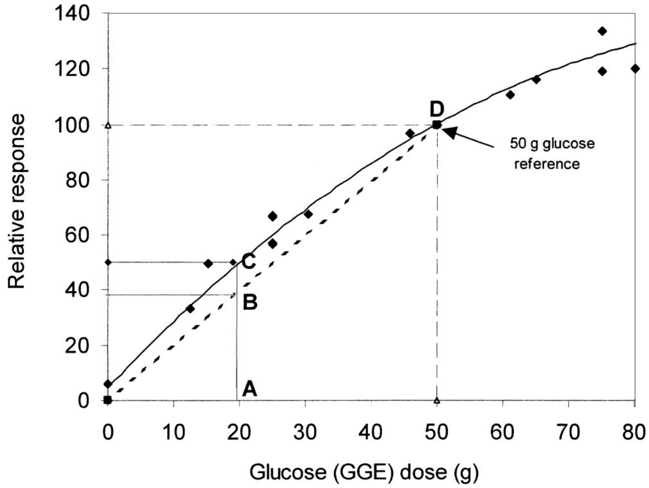

FIGURE 4. The quadratic nature of the glycemic glucose equivalent (GGE) dose–glycemic response curve based on the results of 5 dose-response studies (13-17) normalized to a response of 100 at an intake of 50 g glucose. Linear extrapolation from the 50-g glucose reference underestimates the response to glucose for GGE intakes of <50 g. For a given glucose or GGE dose (A), the response (C) is greater than is predicted (B) by linear extrapolation from the response to a 50-g glucose reference (D), leading to overestimation of GI and GL. Percentage inaccuracies are shown in Figure 5.

Thus, the AACC definition of glycemic impact demands a radical change in measurement procedure from an equicarbohydrate to an equiglycemic determination, that is, from a measurement in which glycemic responses are compared at the same "available" carbohydrate intake to a measurement in which weights of a food and a reference that would induce an equal glycemic response are compared.

It is not possible to exactly position the glycemic effects of a food and a reference without prior knowledge of the food's effect, but many strategies exist that overcome this problem by aligning the food and reference responses closely enough for the effects of nonlinearity to become negligible. For example, one can generate an indicative GL on the basis of an available carbohydrate value adjusted by the GI of its constituent available monosaccharides, particularly if the available carbohydrate content is measured as recommended in the AACC report (2) by in vitro digestion of food as consumed. Second, one can use 2 references, one on each side of the unknown, and measure the equivalent glucose dose by interpolation. Third, one can make a mathematical adjustment on the basis of the equation for the universal dose-response curve, once the separation between responses to the food and to the reference is known. Last, one can read the glucose equivalent off a standard glucose reference curve. This is the most accurate way of measuring GGE (Wallace et al; unpublished observations, 2006).

An advantage of directly measuring glycemic impact as a food property is that there would be no need to use available carbohydrate values, with the additional uncertainty that they introduce.

THE TERMINOLOGY OF GLYCEMIC IMPACT

As a descriptor for the virtual food component data set behind RGI, GGE is a scientific, accurate, and concise term. Descriptors for virtual food components need to make reference to the effect, biomarker, or endpoint that they represent; the reference against which the food effects are measured; and the fact that they do not represent the weight of a reference component per se in a food, but rather the weight of the reference that would have an effect equivalent to that of a given weight of the entire food. Glycemia, glucose, and equivalence are all part of GGE as the minimal descriptor for the data that underpin RGI, as a statement of the relative potential of foods to induce a postprandial glycemic response. The term *glycemic impact* in turn is more scientifically described as relative glycemic impact, with the acronym RGI to distinguish it from GI and GL.

The term *glycemic load* is often used without units and sometimes with the unit (g), but little about the term indicates what it means or that it does not represent a weight of glucose but rather a relative effect or an accumulation of relative effects. GI is a greater problem. An index by definition is "a number expressing a physical property in terms of a standard." The GI of a food should therefore express the glycemic potency of a food relative to a glucose standard. However, the GI in current use is the imputed GI of available carbohydrate in a food, not a GI of food per se. The misattribution of GI to foods rather than to food carbohydrates has caused confusion among both professional and lay users of GI.

COMMUNICATING GLYCEMIC IMPACT

Because glycemic impact is based on the virtual food component GGE, it may be easily communicated in exactly the same way as any other food component as grams per serving and as grams per 100 g of food. Glycemic impact would be measured per serving or per other relevant quantity, and extrapolation to 100 g would allow food comparisons on an equal weight basis.

In a food label, several options are available for communicating glycemic impact. Two alternatives are shown in Table 1. In the top half of the table, GGE as a virtual food component is included with other food components in the nutrient information panel, which supports glycemic impact as a consumer signpost

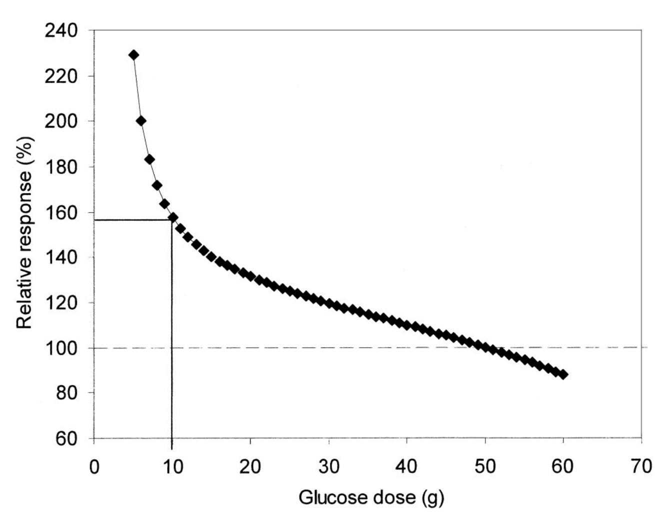

FIGURE 5. Glycemic response per gram of glucose changes with glucose dose; thus, glycemic responses to a food and a reference should be closely aligned to accurately and directly determine the weight of glucose equivalent in effect to a given weight of food, ie, its glycemic impact. The above example shows that for a 50-g carbohydrate dose with a GI of 20 (GGE ≈ 50 × 0.2 = 10), the response would be overestimated by ≈60%. The reference response at a 50-g glucose reference intake is set at 100% (GI = 100).

external to the nutrient information panel. In the bottom half of the table, glycemic impact is included in the nutrient information along with its supporting GGE units.

Which format is the most correct depends on the purpose of a nutrient information panel. If the aim is to present an accurate and unambiguous summary of major components in a food, glycemic glucose equivalents (g) should appear, because the terms *glycemic load* and *glycemic impact* themselves give no information about what the load or impact consists of. However, if the main purpose of a nutrient information panel is communication with consumers, *glycemic impact*, when clearly defined as the glucose equivalent of a specified amount of food, a serving and 100 g, may be appropriate.

The GL calculated from the GI is being increasingly used in the same way as it is intended that glycemic impact be used and is often presented without units. The idea of a load has intrinsic meaning, but as a food value it requires units. Because it is currently calculated from the GI, it contains the nonlinearity error due to changing glycemic responsiveness with dose, as discussed above. If GL is to be used to communicate glycemic impact, it should be measured equiglycemically if it is to represent the glucose equivalent of a food quantity and would then bear GGE or at least glucose equivalent units. GGE may also serve as the acronym for "grams of glucose equivalents" once the glycemia context of the value has been defined.

MANAGING GGE VALUES UNDERPINNING GLYCEMIC IMPACT

With the development of modern food-composition database systems and their ability to be interfaced with electronic health care systems, such as blood glucose monitors and insulin pumps, there is increased opportunity for glycemic impact to be integrated into nutritional management that is responsive to an individual's physiologic or health status. The interrelationship of GI or GL with GGE and available carbohydrate values in a food-composition database and their potential connection to nutritional management are summarized in **Figure 6**.

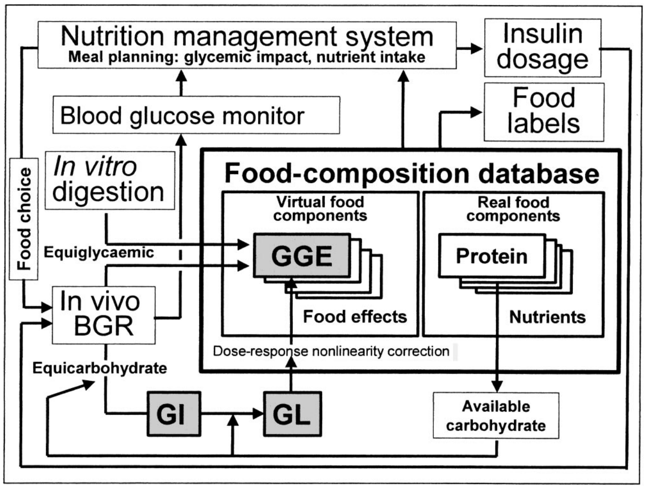

FIGURE 6. A glycemic glucose equivalent (GGE) database derived from a range of sources [clinical measurements = glycemic index (GI) × available carbohydrate = glycemic load (GL), in vitro digestion] embedded in a food-composition database containing real and virtual food components. The food-composition database may be interfaced with nutrition-management systems that combine the real and virtual food components to give a more complete nutritional profile of a food intake than can be provided by real food components alone. BGR, blood glucose response.

For food-composition databases to be usefully integrated into nutrition management systems, as depicted in Figure 6, it is necessary that they be comprehensive enough to include most currently consumed foods. At present, although there already exists an urgent need for data to support healthier food choices, the available number of virtual food component values is too small to constitute a practical working database.

The problem of lack of virtual food component data can be partly overcome by generating interim data to fill existing gaps, in the same way that food-composition databases have relied on carefully selected values from other databases, until these interim values can be replaced by indigenous analytic values. Such values would represent different degrees of improvement over available carbohydrate alone.

Although highest quality GGE data are obtained by measuring the effect of a food directly in humans, clinical determinations are too expensive and slow to keep pace with the rate of appearance of new food products. However, additional surrogate GGE values may be obtained in several ways. Such GGE estimates may be attached to "confidence codes" in the database, which identify the source of the GGE values and are linked to other key information, such as their precision and accuracy.

Approximate GGE values may be obtained from existing GI × available carbohydrate, and GL values, but require a correction for the nonlinearity effects due to separation of the reference and food responses in GI determination, as discussed above. They are also subject to error imported from currently available carbohydrate values. A cheap and practical alternative is to obtain measurements from in vitro digestion methods, which are highly precise because they avoid subject variation and show reasonable accuracy as predictors of glycemic response (19-21). Indeed, if the AACC recommendation (2) that available carbohydrate be measured by digestive analysis of foods as consumed were adopted, available carbohydrate would become a reasonable approximation for GGE for foods in which the effects of food structure and carbohydrate composition are major determinants of the glycemic response.

FUTURE DEVELOPMENTS IN GLYCEMIC IMPACT

In the definition of glycemic impact, the underlying glucose equivalence is based on an equivalent glycemic response. But what exactly constitutes a glycemic response is not specified more precisely than "a change in blood glucose concentration." At present, response is taken to mean the IAUC for 2 h after consuming food, without taking into account the response pattern in that time, so it is a crude measure.

As our understanding of which features of the postprandial change in blood glucose concentration are critical to health outcomes improves, the perceived importance of various characteristics of the response, such as slope and amplitude, may change. However, as long as glucose is used as the reference against which responses to foods are standardized, and there is agreement about which characteristics of the postprandial glycemic response are most closely linked to health outcomes, the terms *glycemic impact* and *GGE* will remain valid, although the parameters of the glycemic equivalence on which they are based may be refined.

CONCLUSION

Glycemic impact is a term for the total grams of glycemic glucose equivalents consumed in a food. It is well suited to be a guide to food choices for glycemic control, because it behaves as if it were a food component and may be expressed in the same format as nutrients, as grams per serving, per 100 g, or per a given amount of food. It therefore satisfies the demand for a food value that expresses potential, relative glycemic effect, as "grams per serving of food" (2). Accurate measurement of glycemic impact requires a change in methodology to provide a comparison of food quantities giving an equivalent glycemic response, in contrast with the current approach of comparing glycemic responses at an equal available carbohydrate intake, as used in GI determination.

GI and GGE represent only the glycemia dimension in nutritional management and are not intended for use in isolation. The metabolic effects of using either GI or GGE depend on the nutritional management that accompanies their application. When foods have been classified into groups of similar nutrient composition, GI and GGE provide similar rankings of foods, because the GI is approximately the GGE content of 50 g carbohydrate expressed as a percentage.

The main benefit of GGE values will be in their acting as a virtual food component that underpins glycemic impact as a food property, which can be used alongside other nutrient information and which responds to changes in food composition and intake that determine glycemic effect. GGE values therefore have a role to play in food-composition databases and nutrition management systems that combine the nutrient and functional attributes of foods, including their glycemic impact.

The contributions of the authors were as follows—JAM: wrote the article; MS: had the idea of combining normalized results from several studies to provide a universal glucose dose–glycemic response curve, as shown in Figure 4. JAM had no conflicts of interest. MS owns The Good Carb Food Co Ltd, Llanelli, Wales, which uses glycemic load and glycemic glucose equivalents in nutrient information panels on some products.

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