# A Method for Adding Glycemic Load Values to a Food Frequency Questionnaire Database

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# Origins of Glycemic Index

- Otto and Niklas (1980)
  - Classify foods in terms of glycemic response
  - For use in management of diabetes

- Jenkins, Wolever, *et al.* (1981)
  - Independently develop “Glycemic Index” as classification of glycemic effects of food
  - For use as supplement to chemical composition information contained in food tables

# What is “Glycemic Index”

- A measure of the glycemic effect of carbohydrate from specific food compared to pure glucose (or white bread)
- Determined directly for individual foods through feeding studies

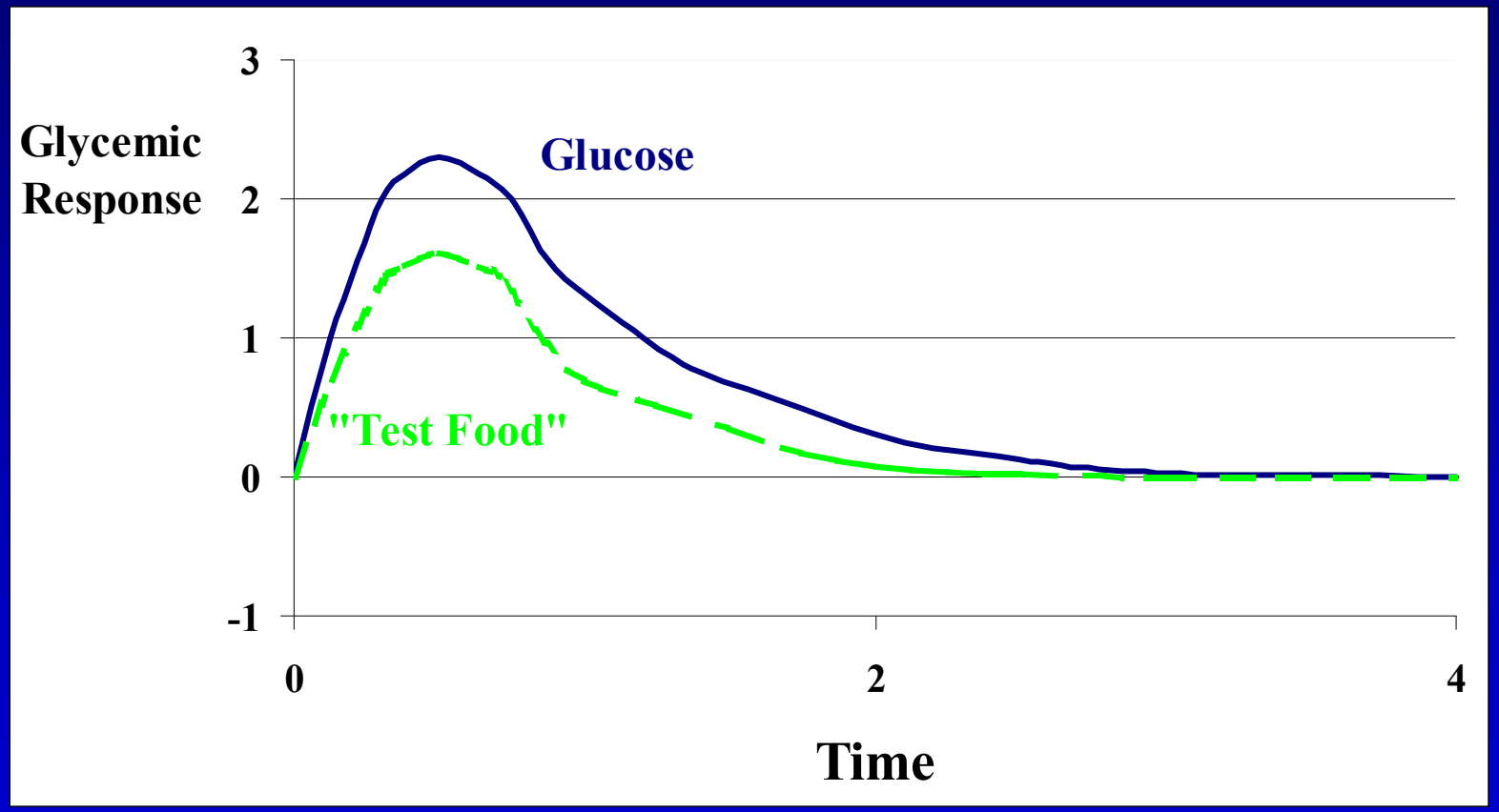
# Glycemic Index Compares "Carbohydrate Equivalents"

- Glycemic response of 50 grams of glucose

*vs.*

- Glycemic response of a quantity of "Test Food" that provides 50 grams of carbohydrate

# Feeding Study of “Test Food”



# Calculating Glycemic Load for an Individual Serving of a Specific Food

$$\mathbf{GL_{food} = (GI_{food}/100)\ (CH_2O_{food})}$$

(Units for GL are “gram equivalents of pure glucose”)

# Calculating Total Dietary Glycemic Load

$$GL_{diet} = \Sigma\ (GI_{food}/100)\ (CH_2O_{food})\ (Servings_{food})$$

# Glycemic Load is a “Nutrient”

- Glycemic Index is unique to each food
- Each serving of food provides a specific glycemic load
- Glycemic load is the effective glucose dose of each serving of food
- As a “nutrient” can be thought of as a potentially important etiological exposure in epi studies

# Methods for Adding GL to FFQ Databases?

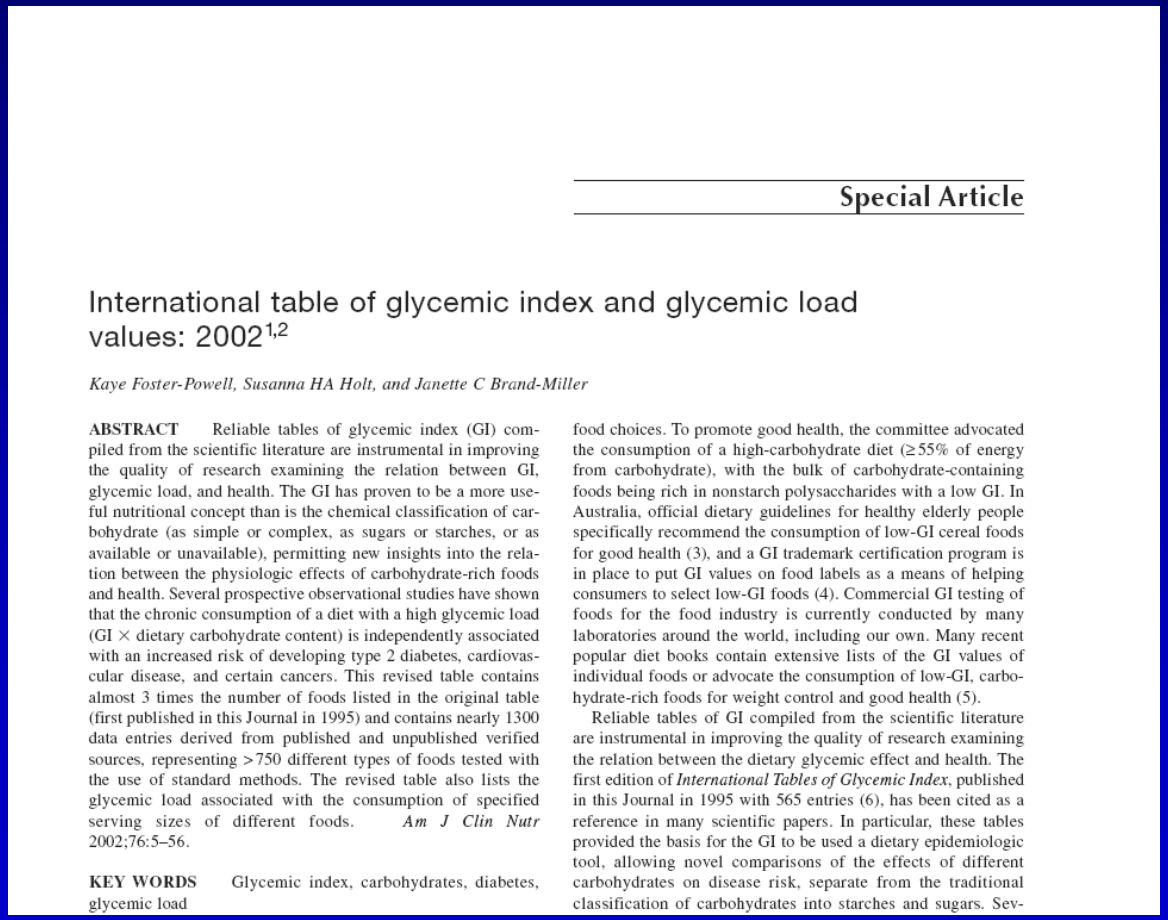
- Not well established, not well-described, not necessarily consistent
- No national food composition tables for GI/GL

# The NCI Diet History Questionnaire (DHQ)

- Based on responses of 10,019 adults to one or two 24-hour recalls in CSFII
- 5,261 distinct foods mentioned in CSFII
- Categorized into 336 mutually-exclusive groups
- 225 of these groups selected for inclusion as line items in the DHQ

| CSFII food group on NCI DHQ | Foods from CSFII in the NCI DHQ database | Number of times mentioned by respondents to CSFII |
|---|---|---|
| **Oranges, tangerines, tangelos** | 1. Orange, raw | 941 |
| | 2. Orange, mandarin, canned or frozen, NS as to sweetened or unsweetened; sweetened, NS type of sweetener | 12 |
| | 3. Orange, mandarin, canned/frozen, lt syrup | 2 |
| | 4. Orange, mandarin, canned or frozen, drained | 9 |
| | 5. Tangelo, raw | 10 |
| | 6. Tangerine, raw | 81 |
| | | **1,055** |

# Database of Calculated Glycemic Index Values



Special Article

International table of glycemic index and glycemic load values: 2002[1,2]

*Kaye Foster-Powell, Susanna HA Holt, and Janette C Brand-Miller*

**ABSTRACT** Reliable tables of glycemic index (GI) compiled from the scientific literature are instrumental in improving the quality of research examining the relation between GI, glycemic load, and health. The GI has proven to be a more useful nutritional concept than is the chemical classification of carbohydrate (as simple or complex, as sugars or starches, or as available or unavailable), permitting new insights into the relation between the physiologic effects of carbohydrate-rich foods and health. Several prospective observational studies have shown that the chronic consumption of a diet with a high glycemic load (GI × dietary carbohydrate content) is independently associated with an increased risk of developing type 2 diabetes, cardiovascular disease, and certain cancers. This revised table contains almost 3 times the number of foods listed in the original table (first published in this Journal in 1995) and contains nearly 1300 data entries derived from published and unpublished verified sources, representing >750 different types of foods tested with the use of standard methods. The revised table also lists the glycemic load associated with the consumption of specified serving sizes of different foods. *Am J Clin Nutr* 2002;76:5–56.

**KEY WORDS** Glycemic index, carbohydrates, diabetes, glycemic load

food choices. To promote good health, the committee advocated the consumption of a high-carbohydrate diet (≥55% of energy from carbohydrate), with the bulk of carbohydrate-containing foods being rich in nonstarch polysaccharides with a low GI. In Australia, official dietary guidelines for healthy elderly people specifically recommend the consumption of low-GI cereal foods for good health (3), and a GI trademark certification program is in place to put GI values on food labels as a means of helping consumers to select low-GI foods (4). Commercial GI testing of foods for the food industry is currently conducted by many laboratories around the world, including our own. Many recent popular diet books contain extensive lists of the GI values of individual foods or advocate the consumption of low-GI, carbohydrate-rich foods for weight control and good health (5).

Reliable tables of GI compiled from the scientific literature are instrumental in improving the quality of research examining the relation between the dietary glycemic effect and health. The first edition of *International Tables of Glycemic Index*, published in this Journal in 1995 with 565 entries (6), has been cited as a reference in many scientific papers. In particular, these tables provided the basis for the GI to be used a dietary epidemiologic tool, allowing novel comparisons of the effects of different carbohydrates on disease risk, separate from the traditional classification of carbohydrates into starches and sugars. Sev-

*AJCN* 2002; 76:5-56.

**TABLE 1**
International table of glycemic index (GI) and glycemic load (GL) values: 2002[1]

| Food number and item | GI[2] (Glucose = 100) | GI[2] (Bread = 100) | Subjects (Type and number) | Reference food and time period | Reference | Serving size | Available carbohydrate | GL[3] (per serving) |
|---|---|---|---|---|---|---|---|---|
| | | | | | | *g* | *g/serving* | |
| **BAKERY PRODUCTS** | | | | | | | | |
| Cakes | | | | | | | | |
| 1 Angel food cake (Loblaw's, Toronto, Canada) | 67 | 95 ± 7 | Type 1 and 2, 9 | White bread, 3 h | 1 | 50 | 29 | 19 |
| 2 Banana cake, made with sugar | 47 ± 8 | 67 | Healthy, 8 | White bread, 2 h | 2 | 80 | 38 | 18 |
| 3 Banana cake, made without sugar | 55 ± 10 | 79 | Healthy, 7 | White bread, 2 h | 2 | 80 | 29 | 16 |
| 4 Chocolate cake made from packet mix with chocolate frosting (Betty Crocker; General Mills Inc, Minneapolis, MN, USA) | 38 ± 3 | 54 | Healthy, 10 | Glucose, 2 h | UO[4] | 111 | 52 | 20 |
| 5 Cupcake, strawberry-iced (Squiggles; Farmland, Grocery Holdings, Tooronga, Australia) | 73 ± 12 | 104 | Healthy, 10 | Glucose, 2 h | UO[4] | 38 | 26 | 19 |
| 6 Lamingtons (sponge dipped in chocolate and coconut) (Farmland, Australia) | 87 ± 17 | 124 | Healthy, 10 | Glucose, 2 h | UO[4] | 50 | 29 | 25 |
| 7 Pound cake (Sara Lee Canada, Bramalea, Canada) | 54 | 77 ± 8 | Type 1 and 2, 10 | White bread, 3 h | 1 | 53 | 28 | 15 |
| 8 Sponge cake, plain | 46 ± 6 | 66 | Healthy, 5 | Glucose, 2 h | 3 | 63 | 36 | 17 |
| 9 Vanilla cake made from packet mix with vanilla frosting (Betty Crocker, USA) | 42 ± 4 | 60 | Healthy, 10 | Glucose, 2 h | UO[4] | 111 | 58 | 24 |
| 10 Croissant (Food City, Toronto, Canada) | 67 | 96 ± 6 | Type 1 and 2, 13 | White bread, 3 h | 1 | 57 | 26 | 17 |
| 11 Crumpet (Dempster's Corporate Foods Ltd, Etobicoke, Canada) | 69 | 98 ± 4 | Type 1 and 2, 13 | White bread, 3 h | 1 | 50 | 19 | 13 |
| 12 Doughnut, cake type (Loblaw's, Canada) | 76 | 108 ± 10 | Type 1 and 2, 10 | White bread, 3 h | 1 | 47 | 23 | 17 |

# Characteristics of GI Table

- 1300 published (or high-quality unpublished GI values
- 750 individual food items
- 22 food groups

# Holes in the GI Table

- Red meat
- Poultry
- Fish
- Avocados
- Salad vegetables
- Cheeses
- Eggs

# The Problem:

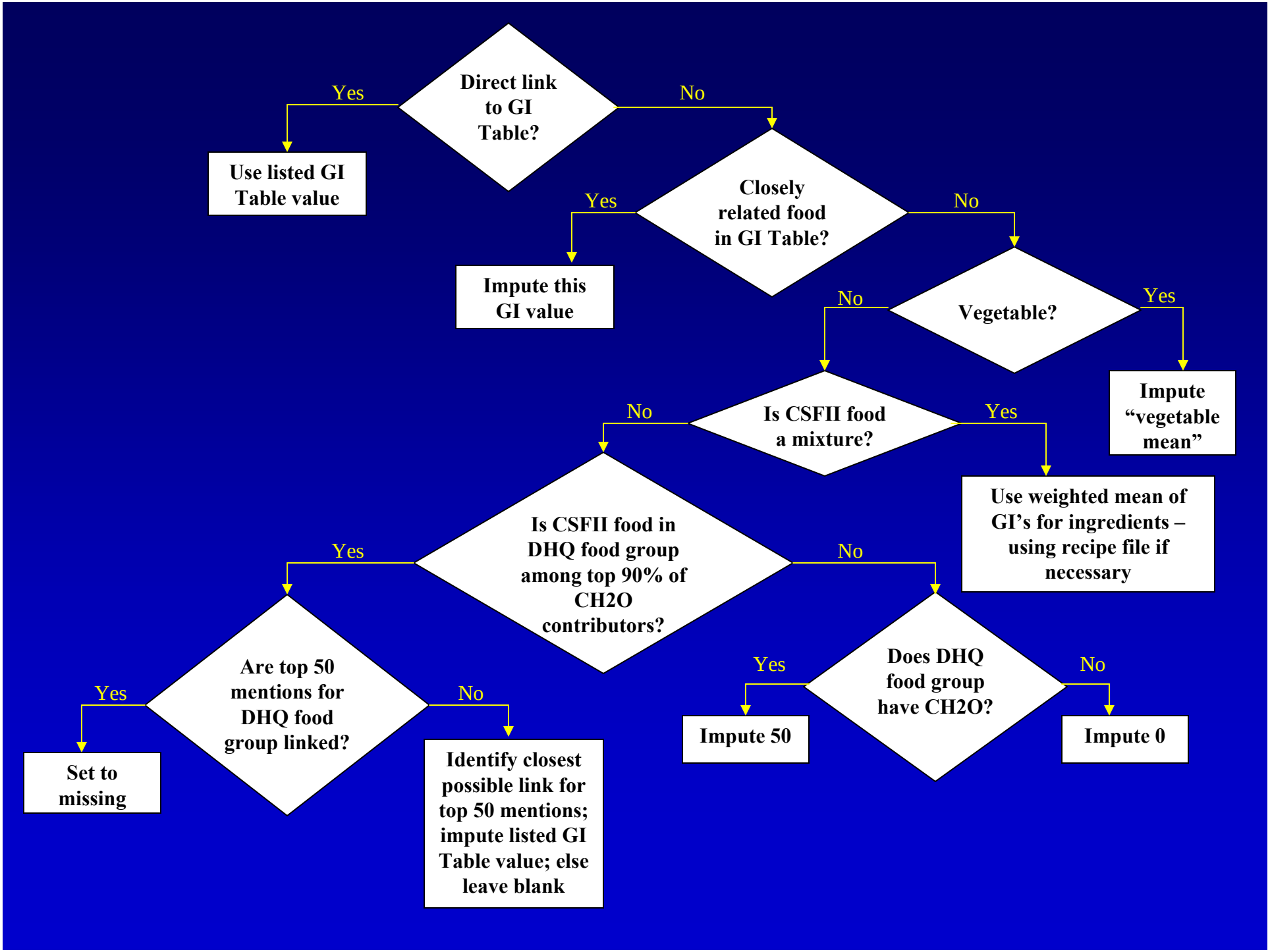
Linking 4,220 individual CSFII foods to roughly 750 GI Table foods to enable assignment of GL values to 225 line items in the DHQ by gender and portion size

# Linkage Methods

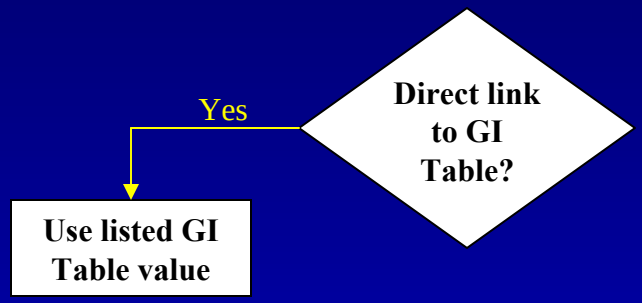
- Nutritionist makes manual review of the GI table for matches to CSFII foods
- Second review of the proposed matches by a second nutritionist

- For GI Table entries with multiple reported values, use mean of reported studies
- Exclude non-U.S. foods on GI Table

- Use linkage algorithm

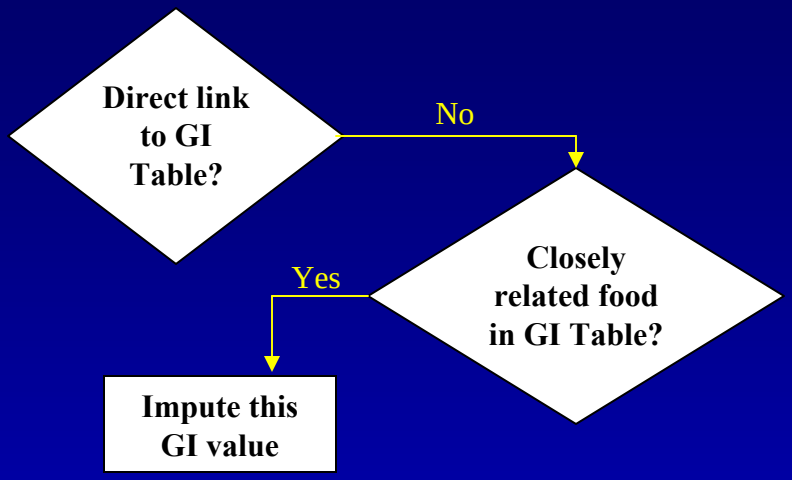

Direct link to GI Table?
Yes
Use listed GI Table value
No
Closely related food in GI Table?
Yes
Impute this GI value
No
Vegetable?
Yes
Impute "vegetable mean"
No
Is CSFII food a mixture?
Yes
Use weighted mean of GI's for ingredients – using recipe file if necessary
No
Is CSFII food in DHQ food group among top 90% of CH2O contributors?
Yes
Are top 50 mentions for DHQ food group linked?
Yes
Set to missing
No
Identify closest possible link for top 50 mentions; impute listed GI Table value; else leave blank
No
Does DHQ food group have CH2O?
Yes
Impute 50
No
Impute 0

# Linkage Algorithm: Step 1



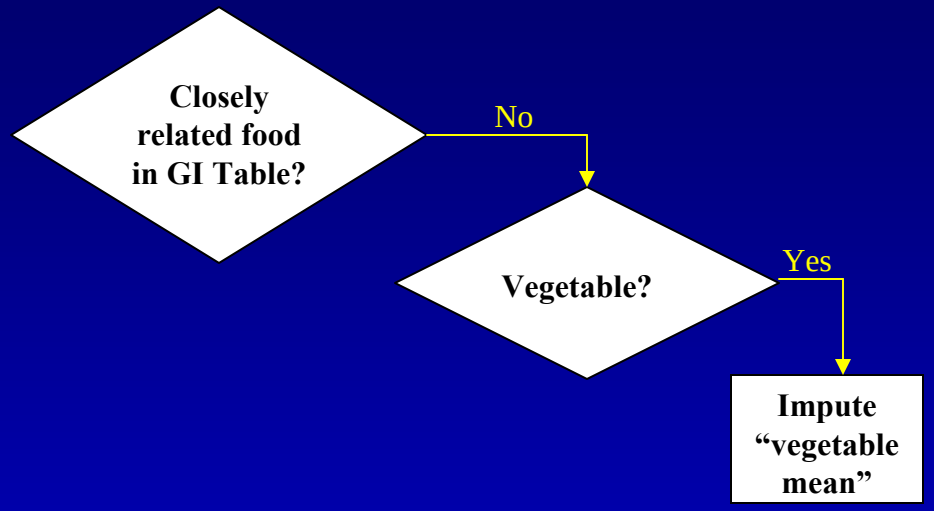

- For direct links, simply use GI-Table value

# Linkage Algorithm: Step 2



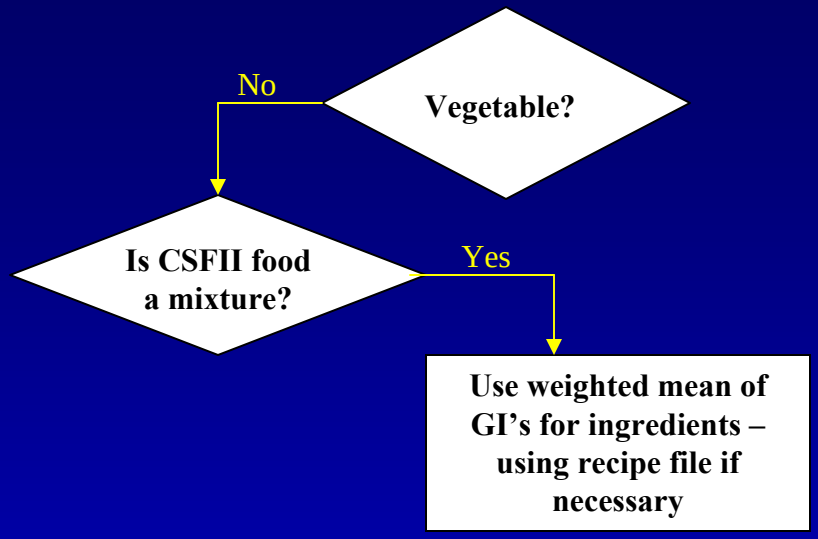

- If not a direct link, determine if there is a closely-related food in the GI Table
- If a closely-related food exists, impute this GI value

# Linkage Algorithm: Step 3



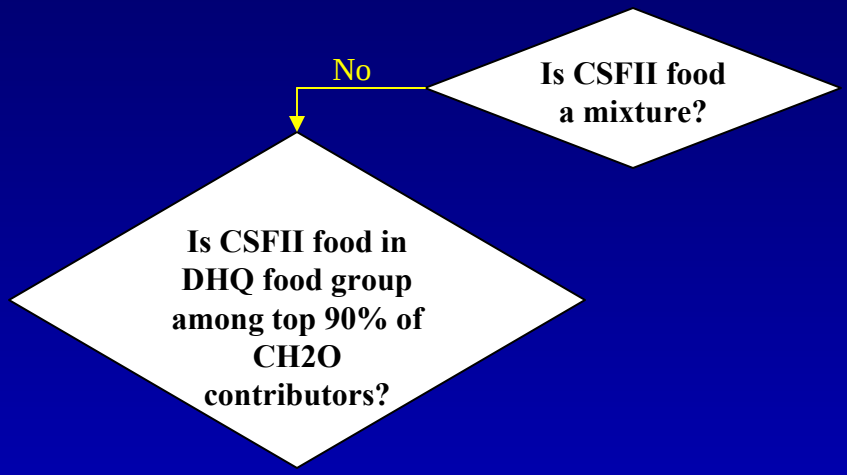

- If not a closely related food, determine if CSFII food is a vegetable
- If a vegetable, use the "vegetable mean"

# Linkage Algorithm: Step 4



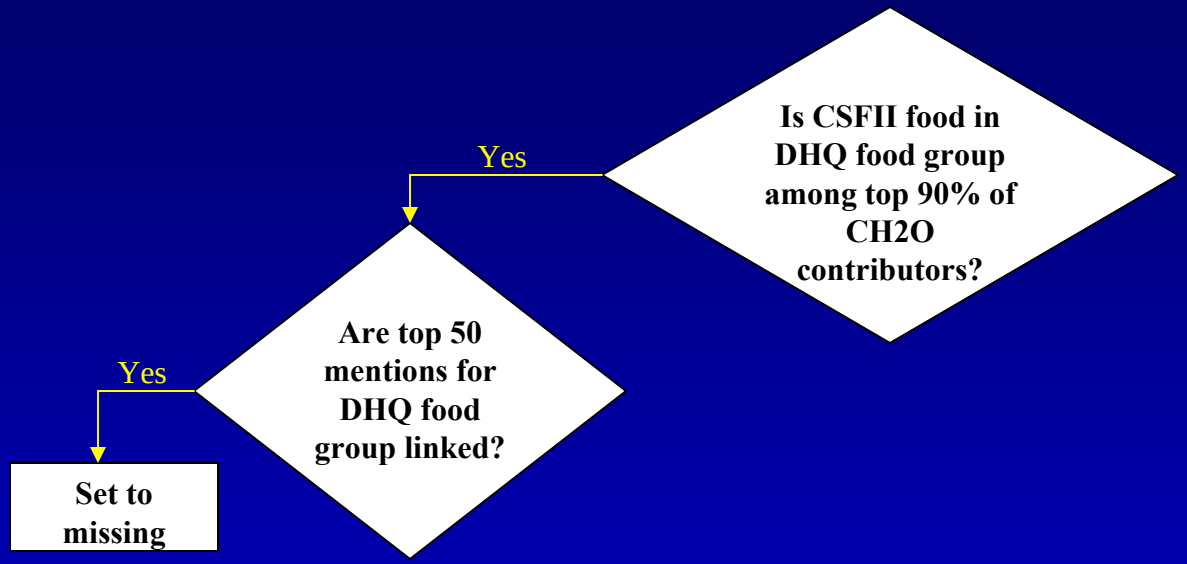

- If not a vegetable, determine if CSFII food is a mixture
- If a mixture use mean of GI's for ingredients, weighted by CH2O content of the ingredients
  - Simple mixtures (*e.g.*, peas and carrots) are straightforward
  - For complex mixtures (*e.g.*, lasagna), consult CSFII recipe file

# Linkage Algorithm: Step 5




- If CSFII food is not a mixture, determine if the CSFII food is in a DHQ food group among the top 90% of CH2O contributors

# Linkage Algorithm: Step 6

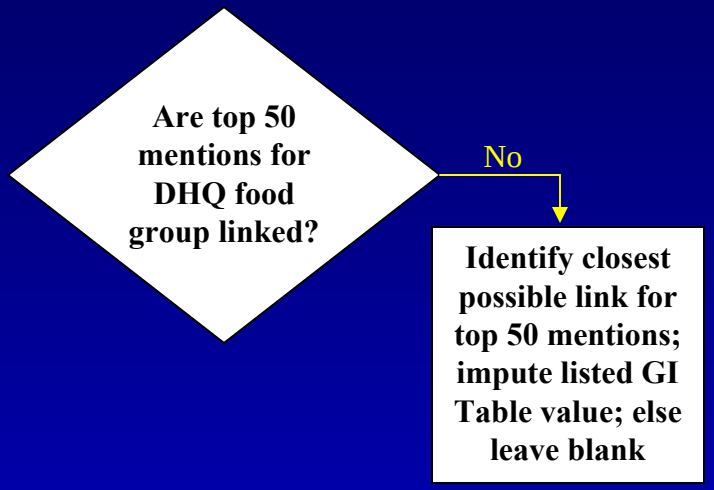



- If DHQ food group is a major CH2O contributor, determine if the top 50 mentions in that DHQ food group are linked
- If yes, then leave blank

| CSFII food group on NCI DHQ | Foods from CSFII in the NCI DHQ database | Number of times mentioned by respondents to CSFII |
|---|---|---|
| **RTE cereal, highly fortified** | 1. Total Corn Flakes | 10 |
| | 2. King Vitaman* | 2 |
| | 3. Product 19 | 28 |
| | 4. Raisin Bran Total | 23 |
| | 5. Total | 146 |
| | | **209** |

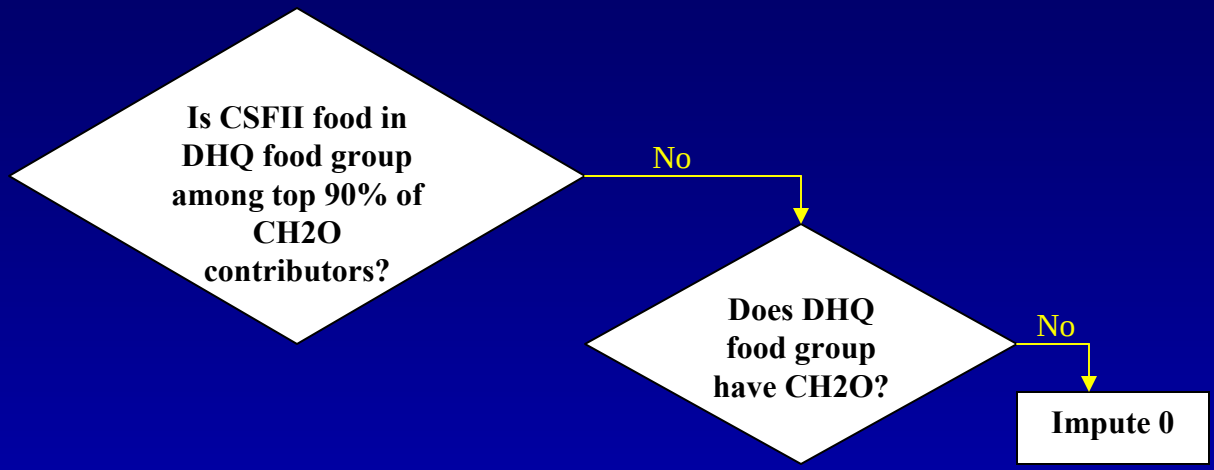
* No link to GI Table

# Linkage Algorithm: Step 7




- If among top 50 mentions for that food group identify closest possible link in GI Table
- Impute the value for that GI Table food; else leave blank

# Linkage Algorithm: Step 8




- If the CSFII food is *not* in a DHQ food group contributing to the top 90% of CH2O, determine if CSFII food is in a DHQ food group with 0 CH2O
- Impute 0

# Linkage Algorithm: Step 9


- If the DHQ food group does have CH2O
- Impute 50

# Calculating Glycemic Load Values in the DHQ

1. Calculate GL for every eating occasion reported in CSFII (excluding foods with unspecified GI values):

$$\mathbf{GL = (GI_{food}/100)\ (CH_2O_{food})}$$

2. For each DHQ food group, medium portion sizes are defined at approximately the 25$^{th}$ and 75$^{th}$ percentile for adults

# Calculating Glycemic Load Values in the DHQ

3. Divide foods consumed at each eating occasion on recalls into small, medium, and large portion sizes for each DHQ food group

4. Determine gender-specific GL by taking the mean of the GL's for the eating occasions in each portion size group identified in step 3

# Fiber?

- GL is an indicator of *glycemic effect* of a given amount of a specific food
- Inherently, relates only to *available* CH2O
- GL calculations in DHQ based on a definition of CH2O as USDA value for *CH2O minus fiber* (includes most resistant starch)

# Quality Assessment

- 41.9% of CSFII mentions (from 25.3% of CSFII foods) linked directly to a GI Table food (*i.e.*, were linked at Step 1 in the Linkage Algorithm)
- For the DHQ food groups contributing top 90% of CH2O in the DHQ, 62.1% of the mentions were linked directly
- Among top CH2O contributors, 9.0% had 100% of their mentions linked directly
- Among top CH2O contributors, 17.3% of the mentions were linked at Step 6 or 7

# Quality Assessment

- 48% of the DHQ food groups in top 90% of CH2O contributors had 100% of mentions linked
- 71% of top CH2O contributors had in excess of 90% of their mentions linked
- 100% of the top CH2O contributors had links for 100% of their top 50 mentions
- 100% of top CH2O contributors had at least 50% of their mentions linked

# Conclusions

- Despite the lack of national nutrient database with GI values, we were able to add GL to the DHQ database
- Quality indicators suggest that we were successful in assigning high-quality GL values for almost all DHQ line items with significant CH2O contribution to the diet

# Conclusions (cont'd)

- With these GL values, it is possible to use the DHQ in large epidemiologic studies of the glycemic effects of food on many chronic disease outcomes
- This method has broad application for investigators using other FFQs who wish to add GL values to their databases

# Conclusions (cont'd)

- GL databases will improve with time as the tables of published GI values are updated with new data for an even broader range of individual foods

# Collaborators

- NCI:

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  Thea Palmer Zimmerman