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## 1 Abstract

2 **Aims:** Dietary glycemic index (GI) and glycemic load (GL) have been associated with risk of  
3 chronic diseases, yet limited research exists on patterns of consumption in Australia. Our aims  
4 were to investigate **glycemic carbohydrate** in a population of older women, identify major  
5 contributing food sources, and determine low, moderate and high **ranges**.

6 **Methods:** Subjects were 459 Brisbane women aged 42-81 years participating in the  
7 Longitudinal Assessment of Ageing in Women. Diet history interviews were used to assess  
8 usual diet and results were analysed into energy and macronutrients using the FoodWorks  
9 dietary analysis program combined with a customised GI database.

10 **Results:** Mean±SD **dietary GI** was 55.6±4.4% and mean **dietary GL** was 115±25. A low GI in  
11 this population was ≤52.0, corresponding to the lowest quintile of **dietary GI**, and a low GL  
12 was ≤95. GI showed a quadratic relationship with age (P=0.01), with a slight decrease  
13 observed in women aged in their 60's relative to younger or older women. GL decreased  
14 linearly with age (P<0.001). Bread was the main contributor to carbohydrate and dietary GL  
15 (17.1% and 20.8%, respectively), followed by fruit (15.5% and 14.2%), and dairy for  
16 carbohydrate (9.0%) or breakfast cereals for GL (8.9%).

17 **Conclusions:** In this population, dietary GL decreased with increasing age, however this was  
18 likely to be a result of higher energy intakes in younger women. Focus on careful selection of  
19 lower GI items within bread and breakfast cereal food groups would be an effective strategy  
20 for decreasing **dietary GL** in this population of older women.

21

22

## 1 **Introduction**

2 Consumption of a diet low in glycemic index (GI) and glycemic load (GL) has been  
3 associated with decreased risk of obesity<sup>1</sup> and chronic diseases, including Type 2 diabetes,  
4 heart disease, ovarian cancer and gallbladder disease<sup>2</sup>. Some studies have not observed a  
5 reduction in disease risk<sup>3,4</sup>, although these studies did not use tools specifically validated to  
6 assess GI and GL. The Dietitians Association of Australia has supported the use of GI in  
7 making food choices<sup>5</sup> and consumer awareness of the GI concept has increased three-fold  
8 from 28% in 2002 to 84% in 2006<sup>6</sup>.

9  
10 GI values for individual foods and beverages have been classified as low ( $\leq 55\%$ ), moderate  
11 (56-69%) or high ( $\geq 70\%$ ) to guide the Australian public in choosing a low glycemic diet<sup>7</sup>.  
12 Although these guidelines have been in the public domain for a number of years, limited  
13 research exists on consumption patterns within the Australian population to determine what  
14 constitutes low, moderate or high **ranges** of dietary GI and GL.

15  
16 Our aims were to: investigate GI and GL consumption in a population of older Australian  
17 women; examine the major contributing food sources; and identify low, moderate and high  
18 **ranges** in this population.

## 20 **Methods**

### 21 *Subjects*

22 A total of 511 women participated in the Longitudinal Assessment of Ageing in Women  
23 (LAW), an age-stratified, multidisciplinary study conducted at Royal Brisbane and Women's  
24 Hospital. Women were randomly selected from the electoral roll (details published  
25 previously<sup>8</sup>). Data for the current study were collected during year three of LAW. Study  
26 procedures were approved by the Human Research Ethics Committees of Queensland

1 University of Technology and Royal Women's Hospital. Subjects gave informed written  
2 consent.

3

#### 4 *Assessment of dietary intake*

5 Usual intake was assessed by a dietitian during a standardised diet history interview<sup>9,10</sup>.

6 Subjects described the amount and type of foods and drinks consumed in a typical month  
7 within the previous six months. Details were obtained on the pattern of food intake throughout  
8 the day with a special focus on carbohydrate-contributing items, including brand names and  
9 preparation methods. Food models and measuring displays were used to assist in  
10 determination of usual serve sizes. Data were analysed into energy and macronutrient intakes  
11 using the FoodWorks dietary analysis program (Professional Version 4.00, Xyris Software,  
12 Brisbane) with the Australian Food and Nutrient Database, combined with a customised GI  
13 database comprising published GI values<sup>11,12</sup>. Where appropriate, values were imputed from  
14 similar foods when the specific brand was not available and GI values for mixed foods and  
15 recipes were estimated from constituents; for example, the GI for trifle was based on a  
16 weighted GI calculation of the carbohydrate-containing ingredients: sponge, jelly and custard.

17

18 Subjects identified as under-reporters of total energy (ratio of reported energy intake to  
19 estimated energy expenditure of  $<0.76$ ) were excluded from the study<sup>13,14</sup>. For a subject to  
20 qualify for a GI and GL score, at least 85% of their carbohydrate intake was required to be  
21 allocated a GI value. **Dietary** GL was calculated as the product of the GI and carbohydrate  
22 content for each food, summed for all foods eaten during the day. **Dietary** GI was calculated  
23 as the product of the GI and carbohydrate content for each food, summed for all foods eaten  
24 during the day and divided by the total daily carbohydrate intake<sup>15</sup>. The **dietary** GI is therefore  
25 the weighted mean GI, proportional to the amount of the available carbohydrate contributed  
26 by each food.

1  
2 The contribution of a food group to carbohydrate intake was calculated by summing the  
3 carbohydrate for each food group and dividing by the total carbohydrate intake for the LAW  
4 women. The contribution of a food group to dietary GL was calculated by summing the GL  
5 for each food group and dividing by overall dietary GL. The contribution of a food group to  
6 dietary GI was calculated by multiplying the percentage of the group's contribution to  
7 carbohydrate intake by the average GI of the food group, and dividing by the sum of this  
8 product from all food groups.

9  
10 *Statistical analysis*

11 Means, SD, medians, interquartile ranges, tertiles and quintiles were used to describe intakes.  
12 Dietary GL was also examined as GL per megajoule of energy to account for energy intake.  
13 Linear regression was used to analyse changes in dietary GI and GL for each year of age, with  
14 models tested for quadratic terms (age-squared) and checked using residual plots. The  
15 Statistical Package for Social Sciences (SPSS) for Windows Graduate Student Version 14.0  
16 was used for analyses.

17

## 18 **Results**

### 19 *Subjects*

20 Of the 511 subjects who commenced the LAW study in year one, 470 subjects completed a  
21 diet history for this study in year three (response rate 92%). Reasons for non-completion  
22 were: unable to attend appointment (n=24), illness (n=13), declined to participate (n=2), and  
23 death (n=2). Of the subjects who completed the diet history, 11 were identified as under-  
24 reporters, resulting in a total of 459 for inclusion in dietary analysis. Of these subjects, 90 did  
25 not meet the criterion of  $\geq 85\%$  of carbohydrate consumed allocated GI values. The remaining

1 369 subjects were used for GI and GL analyses. Characteristics of this group did not differ  
2 significantly from those of the 142 subjects who were not included in the analysis (**Table 1**).

3

#### 4 *Nutrient intakes, dietary GI and GL*

5 Nutrient intakes are shown in **Table 2**. Mean energy intake was 8.5 MJ, with 46.0% derived  
6 from carbohydrate, 18.1% from protein, 32.6% from fat and 3.3% from alcohol; mean **dietary**  
7 **GI** was 55.6 and **dietary GL** was 115. GL showed an inverse linear relationship with age; for  
8 each one-year increase in age, there was an average decrease of 0.4 in GL ( $P < 0.001$ ) (**Table 3**,  
9 **Figure 1**). There was no significant difference in GL per megajoule with age. GI showed a  
10 quadratic relationship with age ( $P = 0.01$ ); values were slightly lower in women aged 60-69  
11 years compared to younger or older women.

12

#### 13 *Foods contributing to **glycemic carbohydrate***

14 Overall, 89.7% of the total carbohydrate intake was able to be allocated a GI value. Food  
15 groups that contributed over 5% to total carbohydrate intake were breads, particularly white,  
16 grain and wholemeal; fruit, particularly bananas and apples; dairy products, particularly milk  
17 and yoghurt; breakfast cereals; potato; and rice (**Table 4**). Food groups that contributed over  
18 5% to total dietary GL were bread products, particularly white, grain and wholemeal; fruit,  
19 particularly bananas and apples; breakfast cereals, particularly oats/porridge, Sanitarium  
20 Weet-Bix™ and muesli; potato; rice; and dairy products (**Table 4**). **The contribution of these**  
21 **food groups to the weighted dietary GI is the same as their contribution to dietary GL, since**  
22 **the GL, by definition, is equal to the GI weighted for the carbohydrate content of the items.**

23

#### 24 *Ranges of dietary GI and GL*

25 When examined in tertiles, low **dietary GI** was  $\leq 53.7$ , medium was 53.8-57.4, and high was  
26  $\geq 57.5$ ; low **dietary GL** was  $\leq 103$ , medium was 104–126 and high was  $\geq 127$ . Cut-points for

1 quintiles were (lowest to highest) 52.0, 54.6, 56.7 and 59.3 for GI and 95, 108, 119 and 134  
2 for GL. If the GI ranges suggested for individual foods<sup>11</sup> were extrapolated to dietary values,  
3 44.2% of subjects were within the low range ( $\leq 55\%$ ), 55.0% were within the moderate range  
4 (56-69%) and 0.8% were within the high range ( $\geq 70\%$ ).

5

## 6 **Discussion**

### 7 *Comparison of diet with other studies*

8 This study examined patterns of **glycemic carbohydrate** in an age-stratified group of older  
9 Brisbane women. Although not representative of the general population, which has  
10 proportionately fewer women in the older age groups<sup>16</sup>, dietary intakes observed in LAW  
11 women were similar to those reported for adult Australian women in the National Nutrition  
12 Survey<sup>17</sup>, with 46.9% of energy derived from carbohydrate, 17.2% from protein, 32.5% from  
13 fat and 2.6% from alcohol. Mean **values** in the LAW study of 56 for GI and 115 for GL were  
14 within the range of values cited in previous studies of 49 to 64 for GI and 96 to 150 for GL,  
15 although comparisons with other studies are made with caution due to differences in dietary  
16 assessment. In these studies, average **dietary** GL was higher (136) in a male population<sup>18</sup>,  
17 intermediate (GL:128-134) in mixed male and female populations<sup>19-21</sup> and lower (GL: 96-116)  
18 in female populations<sup>22-26</sup>, with the notable exception in a group of Japanese women  
19 (GL:150)<sup>27</sup>.

20

21 In the LAW population, GL decreased linearly with age, with values about 15% higher in  
22 younger compared to older women (**Figure 1**). This difference was not significant when  
23 adjusted for the higher energy intake in younger women, using the GL per megajoule measure  
24 (**Table 3**). Higher mean GL values, previously reported in older men<sup>18</sup> and mixed male and  
25 female populations<sup>19-21</sup>, are also likely to be a consequence of higher overall energy intake in  
26 male subjects. GI showed a small but significant quadratic relationship with age, decreasing to

1 a plateau for women in their 60's and increasing for women over 70 years of age. The  
2 increase in the older women could be explained by an increasing preference for relatively high  
3 GI, low fibre items, or by a cohort effect due to cultural changes in food consumption patterns  
4 with time; these possibilities were not explored in this study. In previous research, GI has  
5 tended to be lower (GI: 49-57) in studies that employed food frequency questionnaires<sup>19,20,22-25</sup>  
6 compared with other studies using different methods of dietary assessment (GI: 56-64) such  
7 as 24-hour recalls<sup>26,28</sup>, diet records<sup>27,29,30</sup> or diet histories<sup>18</sup>, although the reason for this trend  
8 is not clear.

9

#### 10 *Foods contributing to glycemic carbohydrate*

11 Differences in glycemic carbohydrate reported in previous studies of older women may be  
12 partially attributed to cultural differences in food consumption patterns. In a group of  
13 Japanese women, Amano et al<sup>27</sup> reported that the largest contributor to carbohydrate intake  
14 was white rice, which has a relatively high GI<sup>12</sup> and may explain the observed high dietary GI  
15 and GL. In a group of American women, with GI and GL values similar to those we found in  
16 the LAW study, Liu et al<sup>25</sup> reported that cooked potato (7.7%), cold breakfast cereal (6.5%)  
17 and white bread (5.2%) were the highest contributors to dietary GL. Although food categories  
18 differed somewhat, this pattern was similar to the LAW study, in which potato contributed  
19 8.3% and breakfast cereals, excluding cooked oats to allow comparison, contributed 7.3% to  
20 GL. White bread (9.8%) and fruit, especially bananas (5.2%), made higher contributions to  
21 GL in the LAW women than the American women. In **Table 4**, we reported the major food  
22 groups in the LAW study women, contributing to carbohydrate and dietary GL. Contributions  
23 to dietary GI were not listed, as conceptually, the contribution of a food group to the dietary  
24 GL is equivalent to its contribution to the weighted dietary GI (that is, weighted by the  
25 percent contribution to total carbohydrate intake), expressed as a percentage of the final  
26 dietary GI.

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## *Optimal ranges of dietary GI and GL*

Currently there are no evidence-based guidelines for optimal dietary GI or GL, although a low GI for an individual food or beverage is classified as  $\leq 55$ <sup>11</sup>. If this criterion is extrapolated to dietary values, 44.2% of LAW subjects would report consuming a low GI diet; 55.0% a moderate GI diet; and less than 1% a high GI diet of  $\geq 70$ <sup>11</sup>. Of five previous studies of dietary GI in older women, four have reported an average GI of less than 55<sup>22-25</sup>, and one study reported a moderate GI of 64<sup>27</sup>. Based on these data and results of the current study, it is questionable whether a cut-off for an average GI of  $\leq 55$  would be appropriate for defining a low GI diet. Our results suggest that a low dietary GI, corresponding to the lowest quintile in the LAW population, would be  $\leq 52.0$ , while a low dietary GL would be less than  $\leq 95$ . In practice, a low GL can mean a diet rich in low GI carbohydrates and vegetables, or a diet low in carbohydrates and high in fat and protein. GL can also vary according to energy intake, giving rise to age and gender-related differences. It is therefore more logical to focus on the choice of lower GI alternatives within high carbohydrate food groups, rather than attempt to define a single GL criterion for men and women of all ages.

A review of glycemic index values<sup>31</sup> reports that most varieties of legumes, pasta, fruits and dairy products are classified as low GI foods, with a GI of 55 or less. Foods such as breads, fruit, breakfast cereals and dairy products were the major contributors to glycemic carbohydrate in the LAW study (**Table 4**). Of these groups, breads and breakfast cereals span a wider range of GI values, while values for fruit and dairy are lower and more uniform<sup>12</sup>. Our study suggests that a focus on careful selection of lower GI items, especially within bread and breakfast cereal groups would be an effective strategy for decreasing GI and GL in this population of older women. Alternatively, the GL could be reduced by consumption of smaller portions of the higher carbohydrate foods. However reducing overall carbohydrate

1 could have implications for achieving the acceptable macronutrient distribution range  
2 (AMDR) of 45-65% of energy intake from carbohydrate, recommended by the National  
3 Health and Medical Research Council<sup>32</sup>, as the mean percentage of energy from carbohydrate  
4 in the LAW study was at the lower end of this range (46%). While the AMDR for  
5 carbohydrate is designed to achieve micronutrient sufficiency and reduce risk of long-term  
6 chronic diseases, qualitative aspects of carbohydrate, including dietary GI and dietary fibre,  
7 are also important.

8  
9 A strength of our study was the diet history assessment, with detailed information on serve  
10 sizes and food types allowing relatively precise characterisation of dietary GI and GL. Use of  
11 a customised GI database allowed 90% of the total carbohydrate intake to be allocated a GI  
12 value, with over 95% allocated for the six most important food groups (**Table 4**). Inaccurate  
13 estimates of dietary GI and GL may have occurred due to the inability to allocate GI values to  
14 some items; for example, within the cake, muffin and scones group (57% allocated), and the  
15 vegetables other than potato group (60% allocated), together contributing just under 9% of  
16 total carbohydrate. However, this limitation was minimised at the individual level by setting  
17 the subject inclusion criterion of  $\geq 85\%$  of carbohydrate allocated a GI value, to ensure that the  
18 score would be representative of the individual's overall diet.

19  
20 To our knowledge, this study is the first to examine age-related differences in a population of  
21 older women and to note a decreasing GL with increasing age. This is a likely consequence of  
22 higher energy intake in younger women rather than qualitative differences in carbohydrate,  
23 although small age-related trends existed in GI and could have contributed. The major sources  
24 of both GI and GL were breads and fruit, followed by dairy for GI and breakfast cereals for  
25 GL. Focus on choice of low GI alternatives within these groups, in particular the breads and  
26 breakfast cereals, would be a feasible way to lower glycemic carbohydrate in this population.

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1 **Table 1.** Characteristics of women in the Longitudinal Assessment of Ageing in Women  
 2 (n=511)  
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Characteristic	Included in	Not included in	P value <sup>1</sup>
	dietary GI and GL analysis (n=369)	dietary GI and GL analysis (n=142)	
Age (years)	61.6	60.3	0.274
Activity level (valid %) <sup>2</sup>			
Active (walk or other activity $\geq 2$ /week)	65.2	65.8	
Sedentary (walk or other activity $< 2$ /week)	34.8	34.2	0.912
Missing (n)	10	22	
Menopausal and hormone therapy (HT) status (valid %) <sup>2</sup>			
Premenopausal	12.7	14.8	
Using HT $> 12$ months	44.1	34.4	0.162
Peri or postmenopausal, and using HT $< 12$ months	43.2	50.8	
Missing (n)	8	14	
Smoking status (valid %) <sup>2</sup>			
Non-smoker	54.6	52.7	
Ex-smoker	36.1	38.2	0.915
Current smoker	9.2	9.1	
Missing (n)	1	11	
Anthropometry (mean $\pm$ SD)			
BMI (kg/m <sup>2</sup> )	26.8 $\pm$ 5.1	27.8 $\pm$ 5.6	0.084
Waist to hip ratio	0.81 $\pm$ 0.1	0.80 $\pm$ 0.1	0.527

- 1 <sup>1</sup>P-value from t-test or chi-square test of characteristic equality in the two groups
- 2 <sup>2</sup>Valid % expresses the proportion of women with this characteristic when missing values are removed
- 3

1 **Table 2.** Nutrient intakes for women participating in the Longitudinal Assessment of  
 2 Ageing in Women

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	<b>Mean±SD</b>	<b>Median</b>	<b>Interquartile range</b>
Energy (MJ) <sup>1</sup>	8.47±1.31	8.40	7.56-9.40
Carbohydrate (g) <sup>1</sup>	225±49	225	193-256
Protein (g) <sup>1</sup>	87.8±16.0	87.1	76.4-96.7
Fat (g) <sup>1</sup>	73.7±20.0	71.7	59.9-84.5
Alcohol (g) <sup>1</sup>	9.69±13.51	2.99	0.00-14.91
<b>Dietary</b> GI <sup>2</sup>	55.6±4.4	55.6	52.6-58.4
<b>Dietary</b> GL <sup>2</sup>	115±25	113	98-130
<b>Dietary</b> GL/MJ <sup>2</sup>	13.7±2.3	13.7	11.9-15.2

4 <sup>1</sup>n=4595 <sup>2</sup>n=369

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1 **Table 3.** Differences in GI and GL with age<sup>1</sup> in women participating in the  
 2 Longitudinal Assessment of Ageing in Women (n=369)

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	Change per one year increase in age	95% CI	P value
Carbohydrate (g)	-0.682	-1.133, -0.231	0.003
Energy (MJ)	-0.040	-0.052, -0.028	<0.001
<b>Dietary</b> GI <sup>2</sup>	-0.718 (age) +	-1.269, -0.167	0.011
	0.006 (age-squared)	0.001, 0.010	0.015
<b>Dietary</b> GL	-0.406	-0.653, -0.159	0.001
<b>Dietary</b> GL/MJ	0.017	-0.005, 0.040	0.133

4 <sup>1</sup>Determined using linear regression, age-squared included in model when significant

5 <sup>2</sup>Age-squared was significant in model

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1 **Table 4.** Percentage contribution of food groups to carbohydrate and GL in the Longitudinal  
 2 Assessment of Ageing in Women, and the percentage of carbohydrate allocated a GI value  
 3 for each food group.

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Food group	% Contribution to carbohydrate	% Contribution to dietary GL	% Carbohydrate allocated a GI value
Bread products	17.1 <sup>1</sup>	20.8 <sup>3</sup>	96.5
Fruit	15.5 <sup>2</sup>	14.2 <sup>4</sup>	96.7
Dairy products	9.0	5.8	94.5
Breakfast cereals	7.5	8.9 <sup>5</sup>	96.1
Potato	5.8	8.3	99.7
Rice	5.3	7.3	99.8
Vegetables other than potato	4.7	2.8	56.9
Cakes, muffins, scones	4.1	3.0	60.1
Pasta	4.0	3.7	97.5
Sweet biscuits	3.2	4.0	98.4
Juice	3.2	2.8	92.6
Crackers	2.3	3.2	94.7
Spreads	2.2	2.1	93.1
Milk, sugar in tea and coffee	1.8	1.6	95.3
Chocolate	1.6	1.4	98.9
Soft drinks	1.6	1.8	91.0
Confectionery	1.5	1.4	67.7
Added sugars	1.4	1.8	99.7
Legumes, nuts, seeds	1.3	0.8	70.8
Condiments, sauces	1.2	0.5	37.0

Ice cream, ice confection	1.1	1.1	94.5
Tomato, tomato products	1.0	0.4	47.8
Cordial	0.7	0.8	94.4
Pastry products	0.6	0.3	51.2
Alcoholic beverages	0.5	<0.1	2.6
Pizzas	0.4	0.4	91.3
Meat and egg products <sup>6</sup>	0.3	0.1	37.1
Desserts <sup>7</sup>	0.3	0.2	64.5
Snack foods, crisps	0.3	0.2	54.2
Nutritional supplements <sup>8</sup>	0.2	0.1	65.6
Flour <sup>9</sup>	0.2	<0.1	<0.1
Other cereals	0.1	0.1	73.6
<b>TOTAL</b>	<b>100%</b>	<b>100%</b>	<b>89.7%</b>

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<sup>1</sup>includes white (7.2%), grain (3.8%), wholemeal (3.4%) breads; <sup>2</sup>includes bananas (4.7%), apples

3

(3.3%); <sup>3</sup>includes white (9.8%), grain (3.5%), wholemeal (4.7%); <sup>4</sup>includes bananas (5.2%), apples

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(2.6%); <sup>5</sup>includes oats/porridge (1.6%), Sanitarium Weet-Bix™ (regular) (1.6%), muesli (1.4%);

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<sup>6</sup>includes sausages, fish, meats in sauce, crumbed meats; <sup>7</sup>includes jelly, pudding, trifle, pavlova;

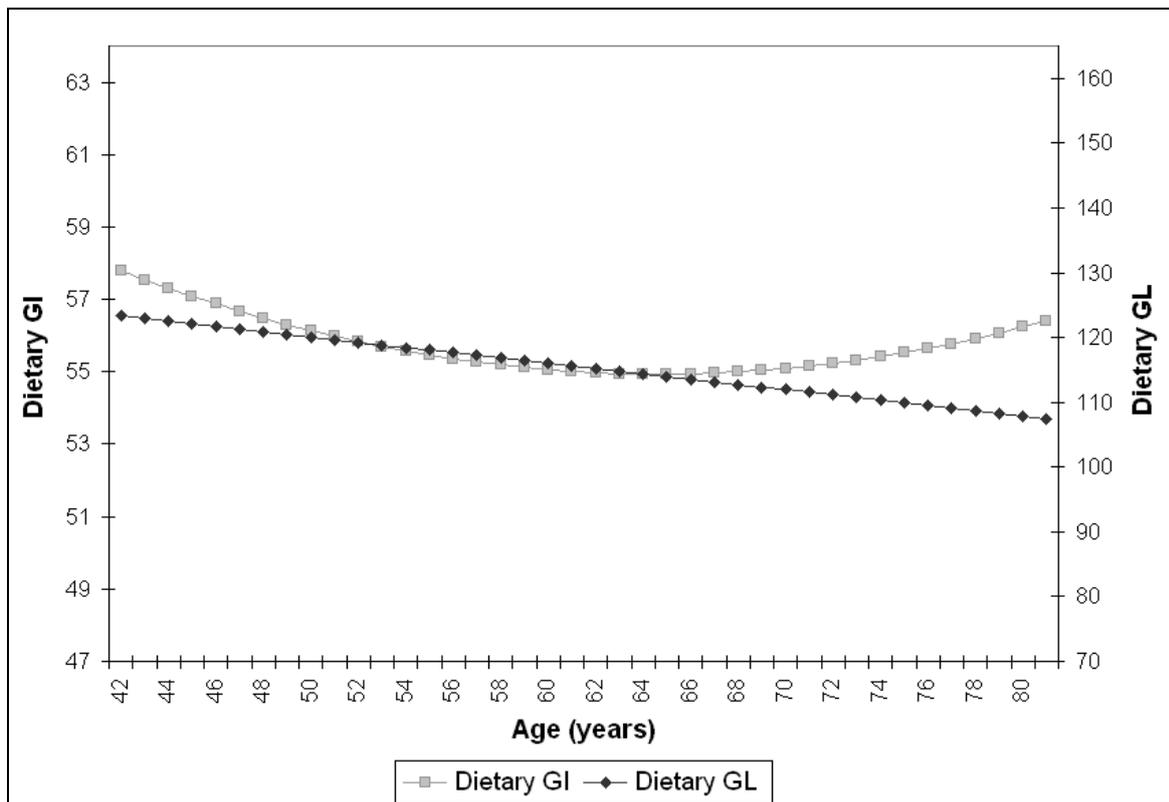
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<sup>8</sup>includes Sustagen, Ensure, Ultra Slim, protein powders; <sup>9</sup>flour listed separately in recipes.

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3 **Figure 1.** Changes in dietary GI and GL for each year of age for women participating  
 4 in the Longitudinal Assessment of Ageing in Women (n=369); GL (P<0.001), GI  
 5 (P=0.013)

6 Scale represents middle 95% range of GI and GL

7 Linear regression equations: expected dietary GI per year=  $78.16 - 0.7181 \times \text{age} + 0.005555 \times$   
 8  $\text{age}^2$ ; expected dietary GL per year=  $140.4 - 0.4062 \times \text{age}$

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