Macronutrient intake, glycaemic index and glycaemic load of older Australian subjects with and without diabetes: baseline data from the Blue Mountains Eye Study

Alan W. Barclay¹, Jennie C. Brand-Miller¹ and Paul Mitchell²,3*

¹School of Molecular and Microbial Biosciences, University of Sydney, NSW, 2006, Australia  
²University of Sydney Department of Ophthalmology, Eye Clinic Westmead Hospital, Westmead, NSW, 2145, Australia  
³Centre for Vision Research, Department of Ophthalmology, University of Sydney, NSW, 2006, Australia

(Received 8 June 2005 – Revised 31 October 2005 – Accepted 31 October 2005)

Individuals with diabetes receive more nutrition advice than other population segments yet little is known about how well they comply or differ in nutrient intake from the rest of the population. The present study determined the mean macronutrient intake, glycaemic index (GI), and glycaemic load (GL) of a cohort of 3654 older Australians, with and without diabetes. Fasting pathology tests, including plasma glucose, were obtained for 88% of the 3654 residents, and a 145-item semi-quantitative food-frequency questionnaire was completed by 2900 residents (89%) between 1992 and 1994. In total, 6% of participants had diagnosed diabetes. Valid food-frequency data were available for 2736 without and 164 individuals with diabetes. The GI and GL were calculated from a customised database of Australian foods. Individuals with diabetes consumed significantly more protein (P=0.001) and less sugars (P≤0.001) than the general population. Only seven individuals with diabetes (4.3%) met all macronutrient recommendations and only four (2.4%) met fibre recommendations as well. Those with diabetes had a lower mean GI (55 (SD 5) v. 57 (SD 4); P=0.007, respectively) and GL (122 (SD 26) v. 134 (SD 24); P<0.001, respectively) than the general population. In conclusion, older individuals with diabetes living in Australia in the 1990s chose a diet that had significantly more protein and less sugars than those without diabetes. This difference had little impact on the average GI, but it led to a moderate reduction in the average GL. Only a small percentage, however, was able to meet nutritional recommendations for optimal diabetes management.

Glycaemic index: Glycaemic load: Macronutrient intake: Diabetes: Blue Mountains Eye Study

Management of diabetes includes lifelong adoption of a healthy diet, regular physical activity and use of hypoglycaemic medication and/or insulin to help achieve and maintain near normal glycaemia as possible. In the year 2000, The Australian Diabetes, Obesity and Lifestyle Study (Cameron et al. 2003) estimated that 7% of Australian women and 8% of Australian men aged 25 years or older had diabetes. Based on these estimates, there were approximately 1.2 million individuals with diagnosable diabetes living in Australia in the year 2004, with half not knowing they had the condition (Diabetes Australia, 2004). The annual total cost of diabetes to the Australian community is in excess of US$ 4.4 billion (Diabetes Australia, 2004).

Approximately 85–90% of all cases of diabetes in Australia are type 2 (Diabetes Australia, 2004), which is characterised by insulin resistance and relative insulin deficiency (American Diabetes Association, 2004). Lifestyle factors including smoking, physical inactivity, excessive energy intake and associated overweight or obesity are established risk factors for the development of type 2 diabetes (van Dam, 2003).

Because carbohydrate is the main dietary component affecting postprandial glycaemia, it has also been implicated in the aetiology of type 2 diabetes (Brand-Miller, 2004). Both the amount and type of carbohydrate consumed have an impact on postprandial glycaemia, and the difference cannot be explained by glucose chain length (Wahlqvist et al. 1978). In the early 1980s the concept of the glycaemic index (GI) was introduced by Jenkins et al. (1981) to quantify the glycaemic responses to carbohydrates in different foods. Glycaemic load (GL), the mathematical product of the GI of a food and its carbohydrate content, has been proposed as a global indicator of the glucose response and insulin demand induced by a serving of food (Salmeron et al. 1997b).

Overall dietary GI and/or GL have been positively related to diabetes risk in three large cohort studies in the USA (Salmeron et al. 1997a,b; Schulze et al. 2004), but no association was seen in two other studies (Meyer et al. 2000; Stevens et al. 2002).

The Blue Mountains Eye Study (BMES) is a population-based cohort study of vision and common eye diseases in an urban population that was aged 49 years or older, and resident

Abbreviations: BMES, Blue Mountains Eye Study; FFQ, food-frequency questionnaire; GI, glycaemic index; GL, glycaemic load.

* Corresponding author: Professor Paul Mitchell, fax +61 2 9845 8345, email paul_mitchell@wmi.usyd.edu.au
in two postcode regions of the Blue Mountains area west of Sydney, Australia. This area has a stable, homogeneous population, which is representative of Australia for income and socio-economic status (Mitchell et al. 1998).

Individuals with diabetes receive more nutrition advice than other segments of the population yet little is known about how well they comply or differ in nutrient intake from the rest of the population. The goal of this initial analysis was to determine the mean macronutrient intake, GI and GL of older Australians with and without diabetes, using detailed nutrient intake data obtained from the BMES. A secondary goal was to compare the nutritional habits of participants with diabetes with those of the background population and to evaluate compliance with nutritional recommendations current at the time of the initial survey. These baseline data will be used to determine associations between key macronutrients, GI and GL, and the risk of developing type 2 diabetes in the BMES prospective cohort study.

**Methods**

The methodology used in the BMES has been previously described (Attebo et al. 1996), and is presented in Fig. 1. Briefly, the present study concerns the baseline study, BMES I, which identified 4433 eligible non-institutionalised permanent residents in a door-to-door census conducted during 1991, of whom 3654 (82·4 %) participated in detailed examinations during the period from 1992 to 1994. Of the 779 (17·5 %) individuals identified in the census who did not participate, 353 (80·0 %) permitted only an interview, 148 (3·3 %) refused, 210 (4·8 %) had moved out of the area, and sixty-eight (1·5 %) had died before the examinations were conducted. The overall response was 82·4 %, though after excluding the latter two groups, it was relatively high at 87·9 %. Baseline differences between participants and non-participants were minimal (Attebo et al. 1996).

All study participants were invited to attend a local clinic for a medical history and examination, which included anthropometry, history of diabetes and associated risk factors. Fast- ing pathology tests, including plasma glucose, were obtained for 88 % of the 3654 residents on a second visit (Mitchell et al. 1998), and a validated 145-item semi-quantitative food-frequency questionnaire (FFQ) was completed by 3269 (89 %) of the residents (Smith et al. 1998).

Participants with at least 10 % of values missing from their FFQ were excluded, as were those with calculated daily energy intakes less than 2500 kJ or greater than 18 000 kJ (Willet & Stampfer, 1986). In total, 367 individuals were removed from further analysis (Smith et al. 1998), leaving a total of 2900 (89 %) individuals with usable FFQ. The FFQ contained additional questions about the type of breakfast cereals used to increase the accuracy of the GI and GL calculations.

A validation study of the FFQ was conducted, using weighed food records as a comparative dietary collection method, collecting 4 d weighed foods records on three occasions over 1 year (n 79) (Smith et al. 1998). The FFQ was found to show moderate to good agreement for carbohydrates and fats, yielding a correlation coefficient of 0·57 and correctly classifying nearly 80 % of individuals within one quintile for carbohydrate, and a correlation coefficient of 0·68 and correctly classifying over 70 % of individuals within one quintile for total fat (Smith et al. 1998). The correlation coefficient for protein was 0·18, and 62 % of individuals were classified within one quintile (Smith et al. 1998).

A dietitian coded data from the semi-quantitative FFQ into a customised database (DBASE IV; Borland International Inc., Scotts Valley, CA, USA) which incorporated the Australian food composition tables (NUTTAB 90; Department of Community Services and Health, 1990) and published GI values using the glucose = 100 scale (Foster-Powell et al. 2002). Additional GI data were obtained from the Sydney University Glycaemic Index Research Service (SUGiRS) online database (www.glycemicondex.com). In total, 88·9 % of the GI values were obtained direct from published values, while the remaining 11·1 % were interpolated from similar food items.

The overall GI of each participant’s diet was calculated by summing the weighted GI of individual foods in the diet, with the weighting proportional to the contribution of the food to total carbohydrate intake. The glycaemic load of each food item was calculated by multiplying each food’s GI by the amount of available carbohydrate (g) per serving. Overall dietary glycaemic load was then determined as the product of food’s glycaemic load and the participant’s frequency of consumption, summed over all foods. Energy and macronutrient...

![Fig. 1. Recruitment process for Blue Mountains Eye Study participants. FFQ, food-frequency questionnaire; FPG, fasting plasma glucose; WFR, weight food record.](https://www.cambridge.org/core/terms. html)
intakes, including protein, fat, saturated fat, available carbohydrate (starch + sugars), total sugars (naturally occurring + added sugars) and fibre were calculated. GI and GL values were adjusted for total energy intake using the residual method (Willett & Stampfer, 1986).

Statistical analyses were performed using SPSS 11.5.0 (SPSS Inc., Chicago, IL, USA). Results are expressed as mean values and standard deviations unless otherwise stated. Comparisons between groups were undertaken using independent-sample t-tests. All data were approximately normally distributed with the exception of alcohol; these data were therefore log-transformed before statistical analysis. Statistical significance was set at P<0.05.

Results
A history of diabetes was reported by 218 (6.0 %) of the 3654 participants, including 11-1 % who had been diagnosed for less than 1 year, 33-6 % for 1–4 years, 19-4 % for 5–9 years, 24-4 % for 10–29 years, and 10-1 % for 20 years or longer. Diabetes duration was not known for 1.4 % of participants.

Among this group, 111 were male (diabetes history in 7.0 %) and 107 were female (diabetes history in 5.2 %). Another sixty-six (2.2 %) had a fasting blood glucose ≥7.0 mmol/l, indicating undiagnosed diabetes. Therefore a total of 8.2 % of participants had diagnosable diabetes, although not all were aware of it.

Of the 218 individuals with a history of diabetes, forty-six (21 %) were treated with insulin, eighty-eight (41 %) with oral hypoglycaemic agents, and eighty-three (38 %) with diet—although not all were aware of it.

Valid height and weight measurements were obtained from 3545 participants. Over half of BMES I participants (56.1 %) were overweight or obese (BMI >25 kg/m2). The mean height of individuals with a history of diabetes was not significantly different from those without (1.65 (SD 0.09) v. 1.65 (SD 0.09) m; P=0.614). However, individuals with a history of diabetes were significantly heavier (76.7 (SD 15.5) v. 70.9 (SD 14.3) kg; P<0.001) and therefore had a higher BMI (28.0 (SD 5.0) v. 26.0 (SD 4.5) kg/m2; P<0.001). Significantly more individuals with a history of diabetes (193 individuals; 70.2 %) were overweight or obese, compared with the general population (1797 individuals; 54.9 %; P<0.001). Key characteristics of individuals with and without diabetes are presented in Table 1.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Individuals with diabetes (n 218)</th>
<th>Individuals without diabetes (n 3436)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>Mean 67.4 ± 8.3</td>
<td>Mean 66.1 ± 9.8</td>
</tr>
<tr>
<td>Female (%)</td>
<td>49.1</td>
<td>57.2</td>
</tr>
<tr>
<td>BMI (kg/m2)</td>
<td>28.0 ± 5.0</td>
<td>26.0 ± 4.5</td>
</tr>
<tr>
<td>Overweight or obese (%)</td>
<td>70.2</td>
<td>54.9</td>
</tr>
<tr>
<td>Fasting plasma glucose (mmol/l)</td>
<td>8.7 ± 4.0</td>
<td>5.0 ± 1.0</td>
</tr>
<tr>
<td>Serum cholesterol (mmol/l)</td>
<td>5.8 ± 1.0</td>
<td>6.0 ± 1.0</td>
</tr>
<tr>
<td>Serum HDL-cholesterol (mmol/l)</td>
<td>1.2 ± 0.4</td>
<td>1.4 ± 0.4</td>
</tr>
<tr>
<td>Serum triglycerols (mmol/l)</td>
<td>2.3 ± 1.0</td>
<td>1.7 ± 1.0</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>150.6 ± 25.0</td>
<td>145.9 ± 21.0</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>83.7 ± 11.0</td>
<td>83.3 ± 10.0</td>
</tr>
<tr>
<td>Time walking (min/d)</td>
<td>27.7 ± 9.9</td>
<td>24.9 ± 10.2</td>
</tr>
<tr>
<td>Time vigorous activity (min/d)</td>
<td>19.1 ± 3.2</td>
<td>17.3 ± 3.6</td>
</tr>
</tbody>
</table>

Discussion
Individuals with diabetes living in Australia in the early 1990s reported eating more protein, fat and saturated fat and less energy, for individuals with a history of diabetes were compared with recommendations from the Diabetes and Nutrition Study Group of the European Association for the Study of Diabetes (Anonymous, 2000) (Table 3). Just over half of the individuals with a history of diabetes had macronutrient intakes within the recommended range for protein, and nearly all were within the range for alcohol, but most consumed more energy from fat and saturated fat, and less energy from carbohydrates than recommended. Only seven individuals with a history of diabetes (4.3 %) were able to meet all macronutrient recommendations and only four (2.4 %) met the recommendations for fibre as well as the macronutrients. Their dietary intake was not appreciably different from other groups of individuals living with diabetes in the developed world, including the Mediterranean basin (Thanopoulou et al. 2004), USA (Banini et al. 2003), Canada (Wolever et al. 1994), Spain (Diabetes and Nutrition Study Group of the Spanish Diabetes Association; Anonymous, 1997) and the UK (Close et al. 1992; Ecley et al. 1996) (Table 4).
available carbohydrate and dietary fibre than recommended for optimal diabetes management. Only a small minority (5%) were able to meet all the macronutrient recommendations and the additional guideline for dietary fibre. The findings suggest that Australians living with diabetes at that time found it difficult to follow dietary recommendations and put excessive emphasis on avoidance of sugars at the expense of other dietary goals. This has been shown to have undesirable consequences for overall nutrient intake, including higher intake of saturated fat (Bolton-Smith & Woodward, 1994; Gibney et al. 1995). The present findings suggest recommendations for individuals with diabetes may be unrealistic or even counterproductive, although it is likely that only a minority received education and follow-up support from a dietitian (Close et al. 1992).

To our knowledge, the present study is the first report of dietary GI and GL of a large representative free-living population of individuals with type 2 diabetes. The GI provides a measure of carbohydrate quality (its glycaemic potential), while the GL takes account of both quantity and quality of carbohydrate and provides a global measure of overall postprandial hyperglycaemia (Wolever et al. 1994; Ceriello et al. 2004). However, at the time of data collection (the early 1990s), the GI was not being applied in general clinical practice, and it is unlikely that any individual received advice on low-GI foods. The mean GI and GL of 57 and 134 respectively in the BMES I population are higher than the median GI and GL of >88 000 nurses living in the USA in 1990 (53 and 105 respectively converted from the bread to glucose = 100 scale using the factor 0.7; Holmes et al. 2004). The mean GI of the BMES I cohort was lower than that reported of a group of 342 Canadians with diabetes in the early 1990s (60 converted from bread to glucose); however, this group received dietary counselling from a registered dietitian as part of a randomised controlled trial, and estimated nutrient intakes are not likely to be representative of their usual intake (Wolever et al. 1994). The GI value for BMES I is very similar to that of a group of 104 children with type 1 diabetes who were randomised to dietary instruction based on either carbohydrate exchanges or low-GI foods (57 v. 55 respectively; Gilbertson et al. 2001). However, children’s data may not be as reliable because underreporting is more common. Moreover, children may have lower-GI diets than adults because of the nature of their food choices (for example, greater consumption of dairy produce and sweet foods) (Gilbertson et al. 2003). A recent study of thirty-two overweight free-living Japanese women with a mean age of 52 years estimated the mean GI to be 64 and the mean GL.

Table 2. Macronutrient intake, glycaemic index (GI) and glycaemic load (GL) of individuals with and without diabetes in the Blue Mountains Eye Study population (n=2900) (Mean values and standard deviations)

<table>
<thead>
<tr>
<th></th>
<th>Individuals with a history of diabetes (n=164)</th>
<th>Individuals without diabetes (n=2736)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Energy (kJ)</td>
<td>8350</td>
<td>2420</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>97</td>
<td>31</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>78</td>
<td>30</td>
</tr>
<tr>
<td>Saturated fat (g)</td>
<td>30</td>
<td>13</td>
</tr>
<tr>
<td>Polyunsaturated fat (g)</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>Monounsaturated fat (g)</td>
<td>27</td>
<td>11</td>
</tr>
<tr>
<td>Total carbohydrate (g)</td>
<td>214</td>
<td>72</td>
</tr>
<tr>
<td>Starch (g)</td>
<td>102</td>
<td>36</td>
</tr>
<tr>
<td>Sugars (g)</td>
<td>109</td>
<td>48</td>
</tr>
<tr>
<td>Alcohol (g)</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Fibre (g)</td>
<td>29</td>
<td>12</td>
</tr>
<tr>
<td>GI</td>
<td>55</td>
<td>5</td>
</tr>
<tr>
<td>GL</td>
<td>122</td>
<td>26</td>
</tr>
</tbody>
</table>

Table 3. Key macronutrient intake of individuals with diabetes in the Blue Mountains Eye Study compared with recommended targets for optimal diabetes management (Mean values and ranges)

<table>
<thead>
<tr>
<th>Recommended target for individuals with diabetes (European Association for the study of Diabetes; Anonymous, 2000)</th>
<th>Intake of individuals with a history of diabetes (n=164)</th>
<th>Percentage of cohort who achieved the recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein (% energy)</td>
<td>10–20</td>
<td>20</td>
</tr>
<tr>
<td>Total fat (% energy)</td>
<td>25–35</td>
<td>35</td>
</tr>
<tr>
<td>Saturated fat (% energy)</td>
<td>&lt;10</td>
<td>13</td>
</tr>
<tr>
<td>Carbohydrate (% energy)</td>
<td>45–60</td>
<td>41</td>
</tr>
<tr>
<td>Alcohol (% energy)</td>
<td>&lt;5</td>
<td>1·4</td>
</tr>
<tr>
<td>Fibre (g)</td>
<td>≥20</td>
<td>29</td>
</tr>
</tbody>
</table>
Table 4. International comparison of macronutrient intakes of individuals with diabetes compared with recommended targets for optimal diabetes management

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Australia BMES I (n 164)</th>
<th>Mediterranean basin (n 1895)</th>
<th>USA (n 51)</th>
<th>Canada (n 342)</th>
<th>UK BMES I (n 132)</th>
<th>UK DNSGSDA (n 67)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kJ)</td>
<td>8350</td>
<td>6328–10 954</td>
<td>9960</td>
<td>7170</td>
<td>7135</td>
<td>8974</td>
</tr>
<tr>
<td>Protein (% energy)</td>
<td>10–20</td>
<td>20</td>
<td>17.6–21</td>
<td>17</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>Total fat (% energy)</td>
<td>25–35</td>
<td>35</td>
<td>27.2–40.8</td>
<td>45</td>
<td>34</td>
<td>37</td>
</tr>
<tr>
<td>Saturated fat (% energy)</td>
<td>10</td>
<td>13</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Total carbohydrate (% energy)</td>
<td>45–60</td>
<td>41</td>
<td>37.7–53.0</td>
<td>45</td>
<td>45</td>
<td>43</td>
</tr>
<tr>
<td>Alcohol (% energy)</td>
<td>5</td>
<td>1.4</td>
<td>0.3–7.6</td>
<td>2.3</td>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>Fibre (g)</td>
<td>30</td>
<td>28.6</td>
<td>19.0–28.6</td>
<td>17.2</td>
<td>15</td>
<td>23.4</td>
</tr>
</tbody>
</table>

Reference
- Present study
- Thanopoulou et al. (2004)
- Banini et al. (2003)
- Wolever et al. (1994)
- Anonymous (1997)
- Eeley et al. (1996)
- Close et al. (1992)

BMES, Blue Mountains Eye Study; DNSGSDA, Diabetes and Nutrition Study Group of the Spanish Diabetes Association.
than most other countries (Foster-Powell et al. 2002), mini-
mising this potential source of error. While the GI is still con-
troversial, many studies show that postprandial glycaemic
profiles can be predicted from a knowledge of the carbo-
hydrate content and the GI of the component foods (Schulze
et al. 2004; Rizkalla et al. 2004; Diaz et al. 2005).

While a FFQ was used in both the BMES I and the Medi-
terranean Basin (Thanopoulou et al. 2004) study, diet records
were used in other studies. A 3-d diet record was used in the
USA (Banini et al. 2003) study, Canadian study (Wolever
et al. 1994) and the UK study by Eeley et al. (1996). A 7-d
diet record was used in the Spanish study (Diabetes and Nutri-
tion Study Group of the Spanish Diabetes Association; Anon-
ymous, 1997) and in the UK study by Close et al. (1992).
Weighed diet records differ from FFQ in their ability to esti-
mate absolute rather than relative intakes of nutrients, provid-
ing a higher level of specificity than FFQ overall (Willett,
1998). Advantages of diet records over FFQ include non-
reliance on memory and ability to determine exact amounts
of foods eaten (Willett, 1998). However, the process of keep-
ing a diet record may alter an individual’s usual intake, and
food intake may vary considerably over the course of 1
week, and even more so over 1 year (Willett, 1998). Direct
comparison of the results of these studies may therefore be
limited by the different sources of error inherent in the differ-
ent tools used to estimate nutrient intakes.

Since the time of the first BMES examinations in 1992–4,
the GI has become increasingly recognised around Australia.
Diabetes Australia first recommended the use of healthy
low-GI food choices in 1997. Other major diabetes associa-
tions around the world including Diabetes UK (Connor
et al. 2003), the Canadian Diabetes Association (Canadian
Diabetes Association Clinical Guidelines Expert Committee,
2003) and most recently, the American Diabetes Association
(Sherd et al. 2004) now recommend its judicious use in clini-
cal practice. For this reason, it is possible that the BMES II (5-
year examinations) and BMES III (10-year examinations) will
reveal changes in the mean dietary GI and GL of individuals
both with and without diabetes.

Conclusions

We conclude that a representative population of older individu-
als with diabetes living in Australia in the early to mid-1990s
chose a diet that had significantly more protein and signifi-
cantly less sugar than that chosen by individuals without dia-
betes. This difference had little impact on the average GI, but
it led to a modest reduction in the average GL. Moreover, it
made no difference at all to total and saturated fat intakes.
Only a small proportion of individuals with diabetes were
able to meet the nutritional recommendations for the optimal
management of their condition. This may be due to difficulties
in self-selecting diets that meet these recommendations, or to a
lack of education and support from suitably qualified health
professionals.

Acknowledgements

The authors would like to acknowledge Dr Victoria Flood,
Elena Rochtchina and Dr Jie Jin Wang for their advice and
assistance with the preparation of this paper.

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