Long-term effect of dietary fibre intake on glycosylated haemoglobin A1c level and glycaemic control status among Chinese patients with type 2 diabetes mellitus

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Abstract

Objective: Dietary fibre has been linked to lower levels of glycosylated haemoglobin A1c (HbA1c) among diabetes patients. The present study aimed to evaluate the long-term effect of dietary fibre on HbA1c levels among Chinese patients with type 2 diabetes mellitus.

Design: Two cross-sectional surveys were conducted in 2006 and 2011, with the second one being a repeat survey on a sub-sample from the initial one. In both surveys, an in-person interview was conducted to collect information on demographic characteristics and lifestyles following a similar protocol. Dietary intake was assessed with a validated FFQ. Anthropometric measures and biochemical assays were performed at the interview.

Setting: Communities in Pudong New Area of Shanghai, China.

Subjects: Chinese patients (n=934) with type 2 diabetes mellitus.

Results: An inverse association was observed between dietary fibre and glycaemic status indicated by HbA1c level in both surveys, although it was significant only in the first survey. Among 497 patients participating in both surveys, dietary fibre intake at the first survey was inversely associated with uncontrolled glycaemic status at the second survey, with adjusted odds ratios across the tertiles of intake being 1.00, 0.72 (95% CI 0.43, 1.21) and 0.58 (95% CI 0.34, 0.99; P_trend = 0.048). The change in fibre intake was slightly associated with glycaemic status, with each increase in tertile scores of intake linked to a 0.138 % (β = −0.138; 95 % CI −0.002, 0.278) decrease in HbA1c value and a 19 % (OR = 0.81; 95 % CI 0.65, 1.02) reduced risk of uncontrolled glycaemic status at the second survey.

Conclusions: Dietary fibre may have a long-term beneficial effect on HbA1c level among Chinese diabetes patients.

Keywords

Type 2 diabetes mellitus
Dietary fibre
Glycosylated haemoglobin A1c

Type 2 diabetes mellitus (T2DM) is a chronic disease mainly characterized by the disorder of glucose metabolism, which may lead to a variety of specific severe complications such as CHD, stroke, diabetic retinopathy and kidney failure1,2. T2DM and its complications have become a main burden of disease around the world, particularly in developing countries2. Aggressive control of hyperglycaemia, either by medicine or lifestyle intervention, is crucial to decrease the incidence of diabetic complications and the related premature death3-5. As a biomarker reflecting an individual’s average level of blood glucose over past 2–3 months, glycylated haemoglobin A1c (HbA1c) has been associated with the risk of long-term diabetes complications6 and used as the main indicator of glycaemic control status among diabetes patients6. The American Diabetes Association recommends an HbA1c level below 7.0 % as the goal of glycaemic control for diabetes patients6.

There is sufficient evidence to support the role of dietary fibre in improving glycaemic control status in diabetes patients7-9. Evidence is also available for its beneficial effect on prevention of diabetes complications. By following up 7822 US women with T2DM in the Nurses’ Health Study for 26 years, He et al.10 found that

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the highest v, the lowest quintile of intakes of whole grains, cereal fibre, bran and germ were associated with 16% to 31% lower all-cause mortality. Bran intake was inversely associated with CVD-specific mortality. The US Department of Agriculture has recommended a minimum daily fibre intake of 3-5 g/1000 kJ (14 g/1000 kcal) for individuals at high risk for T2DM(13). The American Diabetes Association also suggests that patients with T2DM should increase their consumption of dietary fibre to adjust blood sugar and blood lipids, and thus reduce the risk of diabetic complications(60).

Compared with Western populations, Chinese people usually have more dietary fibre intake(12). The average level of total and soluble fibre intakes in Chinese diabetes patients were reported to reach 26.5 and 10.4 g/d, respectively, in a small-scale hospital-based survey(13), more than the moderate amount recommended by the American Diabetes Association (total 24 g/d; soluble fibre 8 g/d and insoluble fibre 16 g/d)(60). However, both glycaemic control status and complications control were unsatisfactory for Chinese diabetes patients(14).

We previously reported an inverse association between dietary fibre and HbA1c among Chinese patients with T2DM(15). Based on the initial cross-sectional study, we further conducted a repeat dietary survey, aimed to evaluate the long-term effect of dietary fibre intake on glycaemic status among Chinese patients with T2DM.

**Materials and methods**

**Participants**

As described in our previous report(15), 979 prevalent patients with T2DM were recruited in the communities of Shanggang, Zhoujiadu, Huanmu, Puxin, Weifang, Jinlyang, Meiyuan and Jichang in Pudong New Area of Shanghai, China, during the period October to December 2006. These patients were diagnosed with T2DM by physicians according to the 1999 WHO diagnostic criteria: (i) fasting plasma glucose ≥7.0 mmol/l; or (ii) 2-h plasma glucose ≥11.1 mmol/l during an oral glucose tolerance test (75-g glucose load should be used); or (iii) a random plasma glucose concentration ≥11.1 mmol/l in persons with symptoms of hyperglycaemia or hyperglycaemic crisis. After excluding those occurring with a cardiovascular event during the previous 6 months, having advanced congestive heart failure, unstable angina, major depression or dementia, 954 eligible patients with a mean age of 61.5 (±10.1) years were interviewed; 41.7% of these patients were male.

During the period May to July 2011, a repeat survey was conducted for all participants of the first survey using a similar protocol. A total of 508 patients were successfully followed up, with a response rate of 54.4%. Of the 426 individuals lost, eighty-one were deceased or heavily sick, seventy-seven were out of town, eighty-one declined and 187 could not be contacted.

**Data collection**

In both surveys, a face-to-face interview was conducted by well-trained interviewers using a structured questionnaire after obtaining written consent from each participant. The collected information included demographic characteristics, duration of being diagnosed with T2DM, regular exercise (at least three times per week and at least half an hour per time), dietary habits, oral hypoglycaemia drug use and insulin use, and T2DM in first- and second-degree relatives.

At the interview, body measurement was conducted to collect body height, weight, waist circumference and hip circumference for each participant by following a standardized protocol. BMI was defined as weight divided by height squared (kg/m²).

**Dietary assessment**

Dietary intake was assessed using an interview-administered FFQ. The FFQ was modified based on an FFQ whose validity and reproducibility had been evaluated in the same population(16). The FFQ specifies 105 food items, covering 90% of food items commonly consumed by Shanghai citizens. Participants were asked to report the frequency (daily, weekly, monthly, annually or never) and duration (months per year) of their consumption of each food item, as well as the estimated amount for each time they ate in the unit of liang (1 liang = 50 g). The amount of intake was reported in millilitres for liquid foods like milk, juice and beverages, and was further transformed to grams in data analysis. The daily intakes of oil, salt and sugar were calculated as the average level consumed by each member of the participant’s family.

The Chinese Food Composition Tables were utilized to estimate the amount of nutrients from each food item and to obtain glycaemic index (GI) values for most food items(17). For the remaining GI values we referred to Foster-Powell et al.’s report(18). Glycaemic load (GL) was calculated by multiplying a food’s GI (as a percentage) by the net carbohydrates in a given serving(19). The daily GL intake was calculated by summing the GL from each food item consumed, and the average GI intake was further obtained by dividing the daily GL intake by the total net carbohydrate intake. For dietary fibre intake, only insoluble fibre was included. We excluded from the study participants who had extreme values for total energy intake (<3347 or > 16 736 kJ/d (<800 or > 4000 kcal/d) for men, n 5; <2092 or > 14 644 kJ/d (<500 or >3500 kcal/d) for women, n 3) to minimize the potential recall bias, as did previous studies(20).

**Biochemical assay**

In both surveys, a blood sample for biochemical assay was collected from each participant after an overnight fast of at least 10 h. As described in our previous report(15), HbA1c was measured using ion-exchange chromatography on a D85 Glycated Hemoglobin Analyzer (DREW D85;
Statistical analysis

Statistical analyses were conducted utilizing the SAS statistical software package version 9.3. Differences in characteristics and dietary factors between the two surveys were compared using \( \chi^2 \) tests for categorical variables and non-parametric signed-rank tests for continuous variables. Pearson correlation tests were used to evaluate the consistency of the two measures of dietary fibre intake per 1000 kJ/d. An unconditional logistic regression model was applied to estimate the adjusted odds ratios and 95% confidence intervals of dietary fibre intake per 1000 kJ/d with glycaemic control status, which was classified as 'controlled' and 'uncontrolled' by HbA1c level of 7-0%. Dietary fibre intake per 1000 kJ/d was classified into tertile groups and scored as 1, 2 and 3 by sex-specific cut-off points for the first and second surveys, respectively. The change in dietary fibre intake was specifically defined as the difference in tertile scores between the two surveys, and thus yielded five groups respectively. The change in dietary fibre intake was used to estimate the effect of changes in dietary fibre intake on the difference of HbA1c level between the two surveys. All statistical tests were based on two-sided probability and the significance level was 0.05.

Results

Of a total of 934 participants, 508 patients were successfully followed up and 497 donated a blood sample. Compared with the non-participants of the second survey, the participants were significantly younger and less likely to use an oral hypoglycaemia drug and insulin at the first survey. However, no significant difference was observed between the two groups with regard to sex, BMI, family history of diabetes, duration of diabetes and presence of other chronic diseases (data not shown).

Among the 508 patients who participated in both surveys, more family history of diabetes, higher prevalence of hypertension, dyslipidaemia and CHD, more use of an oral hypoglycaemia drug and/or insulin, a higher level of dietary fat but lower levels of energy, carbohydrate, dietary fibre and dietary GL and dietary fibre intakes were observed at the second survey than at the first survey, as shown in Table 1. These patients, however, were more likely to exercise and had lower average BMI at the second survey. No significant difference was observed for intakes of energy-adjusted

Table 1 Characteristics and dietary intake in the two surveys: Chinese patients with T2DM, Pudong New Area of Shanghai (two cross-sectional surveys were conducted in 2006 and 2011)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Participants of first survey (n 934)</th>
<th>At the first survey</th>
<th>At the second survey</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean or n</td>
<td>sd or %</td>
<td>Mean or n</td>
<td>sd or %</td>
</tr>
<tr>
<td>Age (years)†</td>
<td>64.5</td>
<td>10.1</td>
<td>63.8</td>
<td>9.2</td>
</tr>
<tr>
<td>Male gender, n (%)</td>
<td>389</td>
<td>41.7</td>
<td>201</td>
<td>39.6</td>
</tr>
<tr>
<td>Family history of T2DM, n (%)</td>
<td>296</td>
<td>31.9</td>
<td>174</td>
<td>34.3</td>
</tr>
<tr>
<td>Age of T2DM diagnosis (years)†</td>
<td>55.2</td>
<td>10.4</td>
<td>54.8</td>
<td>9.7</td>
</tr>
<tr>
<td>Duration of T2DM (years)†</td>
<td>9.2</td>
<td>6.4</td>
<td>9.0</td>
<td>5.9</td>
</tr>
<tr>
<td>BMI (kg/m²)†</td>
<td>25.8</td>
<td>3.6</td>
<td>25.8</td>
<td>3.6</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>518</td>
<td>55.5</td>
<td>281</td>
<td>55.3</td>
</tr>
<tr>
<td>Dyslipidaemia, n (%)</td>
<td>97</td>
<td>10.4</td>
<td>56</td>
<td>11.0</td>
</tr>
<tr>
<td>CVD, n (%)</td>
<td>132</td>
<td>14.1</td>
<td>70</td>
<td>13.8</td>
</tr>
<tr>
<td>Hypoglycaemia drug use, yes, n (%)</td>
<td>762</td>
<td>81.9</td>
<td>433</td>
<td>85.2</td>
</tr>
<tr>
<td>Insulin use, yes, n (%)</td>
<td>88</td>
<td>9.5</td>
<td>35</td>
<td>6.9</td>
</tr>
<tr>
<td>Exercise, yes, n (%)</td>
<td>434</td>
<td>46.5</td>
<td>247</td>
<td>48.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dietary intake</th>
<th>Median</th>
<th>25th, 75th percentile</th>
<th>Median</th>
<th>25th, 75th percentile</th>
<th>Median</th>
<th>25th, 75th percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kJ/d)</td>
<td>6372</td>
<td>5268, 7594</td>
<td>6322</td>
<td>5188, 7665</td>
<td>4954</td>
<td>3987, 6113</td>
</tr>
<tr>
<td>Dietary fibre (g/d)</td>
<td>8.7</td>
<td>6.2, 12.6</td>
<td>8.7</td>
<td>6.0, 13.0</td>
<td>6.9</td>
<td>4.8, 10.1</td>
</tr>
<tr>
<td>Dietary fibre (g/1000 kJ per d)</td>
<td>1.39</td>
<td>1.00, 1.82</td>
<td>1.39</td>
<td>1.00, 1.84</td>
<td>1.31</td>
<td>0.98, 1.82</td>
</tr>
<tr>
<td>Fat (% of energy)</td>
<td>21.1</td>
<td>16.8, 25.7</td>
<td>22.1</td>
<td>16.9, 26.2</td>
<td>40.8</td>
<td>34.1, 49.6</td>
</tr>
<tr>
<td>Protein (% of energy)</td>
<td>14.7</td>
<td>12.8, 16.8</td>
<td>14.5</td>
<td>13.0, 16.6</td>
<td>15.1</td>
<td>12.0, 17.5</td>
</tr>
<tr>
<td>Carbohydrate (% of energy)</td>
<td>63.4</td>
<td>58.1, 69.6</td>
<td>62.8</td>
<td>57.1, 68.6</td>
<td>43.0</td>
<td>35.8, 49.6</td>
</tr>
<tr>
<td>Dietary GI</td>
<td>60.1</td>
<td>54, 66</td>
<td>60.2</td>
<td>54, 66</td>
<td>35.5</td>
<td>30, 41</td>
</tr>
<tr>
<td>Dietary GL</td>
<td>81.6</td>
<td>65, 100</td>
<td>81.1</td>
<td>64, 100</td>
<td>79.4</td>
<td>62, 101</td>
</tr>
</tbody>
</table>

T2DM, type 2 diabetes mellitus; GI, glycaemic index; GL, glycaemic load.
*Paired \( \chi^2 \) test or signed-rank test.
†Values are presented as mean and standard deviation.

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At first survey, dietary fibre intake was associated with glycaemic control status in both men and women; the tertile cut-off points of dietary fibre intake at the second survey for the 497 participants were respectively 1.02 g/1000 kJ per d (4.26 and 6.75 g/1000 kcal per d) in men and 1.18 and 1.66 g/1000 kcal per d (4.98 and 6.94 g/1000 kcal per d) in women; the tertile cut-off points of dietary fibre intake at the first survey were 1.04 and 1.50 g/1000 kcal per d (4.37 and 6.30 g/1000 kcal per d) in men and 1.12 and 1.72 g/1000 kcal per d (4.67 and 7.19 g/1000 kcal per d) in women.

†Adjusted for age (continuous variable), gender (male/female), BMI (continuous variable), duration of T2DM (continuous variable), physical activity (active/inactive), drug use (no drug/hypoglycaemia drug only/insulin use, dummy variables), family history of diabetes (yes/no), carbohydrate intake per 1000 kcal (continuous variable) and energy intake (continuous variable).

‡The HbA1c level in the first survey (continuous variable) is adjusted for the association of dietary fibre intake per 1000 kJ/d at the first survey and glycaemic control status at the second survey.

**Figure 1** presents the association of dietary fibre and HbA1c level by duration of T2DM. Generally, regardless of the duration of T2DM, patients with higher fibre intake had a lower level of HbA1c. The long-term effect of dietary fibre intake appeared more pronounced than the recent effect (Fig. 1(c) vs. Fig. 1(a) and Fig. 1(b)) and the effect was more evident among patients with longer T2DM duration (Fig. 1(c)).

We further evaluated the association of the changes in dietary fibre intake with the changes in HbA1c level. As shown in Table 3, a borderline association was observed between the change in dietary fibre intake and HbA1c change. Specifically, each increase in tertile scores of dietary fibre intake was associated with a 0.138% decrease in HbA1c level ($\beta = -0.138; 95\%\ CI\ -0.002, 0.278; P = 0.054$) and a 19% (OR = 0.81; 95% CI 0.65, 1.02) reduced risk of uncontrolled glycaemic status at the second survey ($P_{\text{trend}} = 0.070$). The OR of uncontrolled glycaemic status was 1.16 (95% CI 0.63, 2.13) and 1.71 (95% CI 0.82, 3.60) for those with −1 and −2 decrease in tertile scores of fibre intake, and 0.58 (95% CI 0.33, 1.00) and 1.15 (95% CI 0.52, 2.54) for those with +1 and +2 increase in tertile scores, compared with those without change.

**Discussion**

In the present study with two repeat surveys among Chinese patients with T2DM, higher dietary fibre intake was consistently associated with better glycaemic control.
status and showed a long-term protective effect on HbA1c level. To the best of our knowledge, the present study is the first that evaluates the effect of changes in dietary fibre intake on glycaemic status among Chinese diabetes patients. Our results provide preliminary evidence on the beneficial effect of fibre intake on glycaemic control and implicate the potential role of dietary fibre intake in prevention of diabetic complications in this population.

Dietary fibre has been shown to benefit human health in several ways\(^{(11)}\). The mechanism by which dietary fibre reduces the risk of T2DM and diabetes complications is not clear, however. It is suggested that a fibre-rich diet provides limited energy\(^{(23)}\), has longer processing time in metabolism and long-term glycaemic control\(^{(7,25)}\). Numerous experimental studies have indicated that viscous dietary fibres benefit immediate postprandial glucose metabolism and long-term glycaemic control\(^{(23,24)}\). In this population of patients, we did not observe a significant association of dietary fibre intake with glycaemic control status. We also observed an insignificant association of changes in dietary fibre intake with changes in HbA1c level. Interestingly, we found that the beneficial effect of dietary fibre in this patient population was slightly more pronounced among those with longer T2DM duration. These findings implicate a potential long-term protective effect of dietary fibre in Chinese diabetes patients and indicate a possible clinical significance of increasing dietary fibre intake in these patients.

Our study suggests that dietary fibre intake among Chinese diabetes patients may have been overestimated, although the data derived from that single study were not representative\(^{(13)}\). Due to the lower average level of energy intake, however, it is also possible that the absolute intake of fibre was underestimated in the current study.

In the present study, the two measurements of dietary fibre intake were significantly correlated, although with a small correlation coefficient. Moreover, most participants had no or a ±1 score change in tertile scores between two surveys. These results indicate relatively stable dietary habits along the duration of the disease in patients.

In both cross-sectional surveys and the small-scale prospective investigation, we consistently observed an inverse association between dietary fibre and glucose control status. We also observed an insignificant association of changes in dietary fibre intake with changes in HbA1c level. Interestingly, we found that the beneficial effect of dietary fibre intake in this patient population was slightly more pronounced among those with longer T2DM duration. These findings implicate a potential long-term protective effect of dietary fibre in Chinese diabetes patients and indicate a possible clinical significance of increasing dietary fibre intake in these patients.

In this population of patients, we did not observe a significant association of dietary GI and GL intake with glycaemic status, which was not consistent with previous studies\(^{(8,27,28)}\). Due to the generally high correlation between dietary fibre and GI/GL, the null association of GI/GL with glycaemic status in this population is somewhat difficult to explain. Our results appeared not to
Table 3 Association of changes in dietary fibre intake and HbA1c level between the two surveys: Chinese patients with T2DM, Pudong New Area of Shanghai (two cross-sectional surveys were conducted in 2006 and 2011)

<table>
<thead>
<tr>
<th>Change in dietary fibre intake</th>
<th>Glycaemic control status at the second survey</th>
<th>OR for each increase in HbA1c level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HbA1c ≤ 7%</td>
<td>HbA1c &gt; 7%</td>
</tr>
<tr>
<td>Change in tertile scores*</td>
<td>No. of patients</td>
<td>%</td>
</tr>
<tr>
<td>-2</td>
<td>53</td>
<td>10.7</td>
</tr>
<tr>
<td>-1</td>
<td>102</td>
<td>20.5</td>
</tr>
<tr>
<td>0</td>
<td>178</td>
<td>35.8</td>
</tr>
<tr>
<td>1</td>
<td>121</td>
<td>24.4</td>
</tr>
<tr>
<td>2</td>
<td>43</td>
<td>8.7</td>
</tr>
</tbody>
</table>

HbA1c, glycated haemoglobin A1c; T2DM, type 2 diabetes mellitus.
*Difference in tertile scores of dietary fibre intake between two surveys.
†Adjusted for age (continuous variable), gender (male/female), BMI (continuous variable), duration of T2DM (continuous variable), regular exercise (never/ever), drug use (no drug/hypoglycaemia drug only/insulin use, dummy variables), family history of diabetes (yes/no), carbohydrate intake per 1000 kJ/d (continuous variable), dietary fibre intake per 1000 kJ/d at the first survey (by tertiles, dummy variables), energy intake (continuous variable) and HbA1c level at the first survey (continuous variable).
‡Adjusted for age (continuous variable), gender (male/female), BMI (continuous variable), duration of T2DM (continuous variable), regular exercise (never/ever), drug use (no drug/hypoglycaemia drug only/insulin use, dummy variables), family history of diabetes (yes/no), carbohydrate intake per 1000 kJ/d (continuous variable), dietary fibre intake per 1000 kJ/d at the first survey (by tertiles, dummy variables), energy intake (continuous variable) and HbA1c level at the first survey (continuous variable).
analysis or writing of this article. **Conflicts of interest:** All co-authors declare that they have no competing interests. **Ethics:** The study was approved by Fudan University Institutional Review Board (IRB00002408, FWA00002399). **Authors' contributions:** L.X.Y. and L.S. contributed to data collection, data analysis and drafting of the paper. J.Y.J., H.Q., Y.Z., H.Y.W. and L.M.Y. contributed to data collection and quality control. G.Y.Q. contributed to data analysis. G.M.Z., Q.W.J. and Q.S. contributed to revision of the paper. X.N.R. and W.H.X. contributed to study design, statistical analysis and revision of the paper. **Acknowledgements:** The authors are grateful to the study participants and research staff from Community Health Centers in Pudong New Area of Shanghai, China.

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