Taiwanese Vegetarians and Omnivores: Dietary Composition, Prevalence of Diabetes and IFG

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Abstract

Introduction: Vegetarian diets have been shown to improve glucose metabolism and reduce risk for diabetes in Westerners but whether Chinese vegetarian diets have the same benefits is unknown.

Methods: We evaluated the association between diet and diabetes/impaired fasting glucose (IFG) among 4384 Taiwanese Buddhist volunteers and identified diabetes/IFG cases from a comprehensive review of medical history and fasting plasma glucose.

Results: Vegetarians had higher intakes of carbohydrates, fiber, calcium, magnesium, total and non-heme iron, folate, vitamin A, and lower intakes of saturated fat, cholesterol, and vitamin B12. Besides avoiding meat and fish, vegetarians had higher intakes of soy products, vegetables, whole grains, but similar intakes of dairy and fruits, compared with omnivores. The crude prevalence of diabetes in vegetarians versus omnivores is 0.6% versus 2.3% in pre-menopausal women, 2.8% versus 10% in menopausal women, and 4.3% versus 8.1% in men. Polytomous logistic regression adjusting for age, body mass index, family history of diabetes, education, leisure time physical activity, smoking and alcohol, showed that this vegetarian diet was negatively associated with diabetes and IFG in men (OR for diabetes: 0.49, 95% CI: 0.28–0.89; OR for IFG: 0.66, 95% CI: 0.46–0.95); in pre-menopausal women (OR for diabetes: 0.26, 95% CI: 0.06–1.21; OR for IFG: 0.60, 95% CI: 0.35–1.04); and in menopausal women (OR for diabetes: 0.25, 95% CI: 0.15–0.42; OR for IFG: 0.73, 95% CI: 0.56–0.95).

Conclusion: We found a strong protective association between Taiwanese vegetarian diet and diabetes/IFG, after controlling for various potential confounders and risk factors.

Background

The diabetes epidemic in Asia and particularly in China emerged simultaneously with increased meat consumption and higher proportion of energy intake from animal protein and fat [1]. Compared with Westerners, Asians tend to incur diabetes at a younger age and at a lower body mass index (BMI), possibly due to genetic susceptibility in combination with environmental exposures [2]. Vegetarian diets have been associated with a lower prevalence [3] and incidence [4] of diabetes among Seventh day Adventists. Previous clinical trials have shown vegetarian diets improve glycemic control [5] and insulin sensitivity [6]. Although several small studies reported lower glucose level and better insulin sensitivity in Taiwanese vegetarians than omnivores [7–9], no study thus far has examined whether a vegetarian diet protects against diabetes in Chinese ethnic Asian population, a high risk population that may incur diabetes despite having a normal BMI value [2]. Moreover, Asian diets tend to be lower in meat and higher in plant foods compared with Western diet. It remains unknown whether a diet completely avoiding meat and fish would further extend the protective effect of a plant-based diet. In addition, most studies on Asian vegetarians tend to compare vegetarians from religious groups with omnivores from the general population [7]. Religious and spiritual practices (a main determinant of vegetarian dietary practice in Asia) may be associated with social and emotional support which may confound health outcomes [10,11].

This study examines within a Buddhist group, the cross-sectional association between vegetarian diet and two stages of

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impaired glucose metabolism – impaired fasting glucose (IFG) and diabetes.

**Methods**

**The Tzu Chi Health Study**

The Tzu Chi Health Study enrolled 6002 Taiwanese adults, of which 77% were Tzu Chi commissioners – a devoted group of volunteers of the Buddhist Tzu Chi Foundation who receive a free health examination every 2 to 3 years at one of four Tzu Chi hospitals. Tzu Chi Commissioners are required to abstain from alcohol, tobacco, and are encouraged to adopt a vegetarian diet for reasons of compassion and environmental conservation.

The current study was conducted at the Buddhist Dalin Tzu Chi Hospital between 2007 and 2009, where all participants received a health examination during an overnight stay at the hospital. Height was measured on a scale with participants standing erect. Body weight and body fat were measured on a Bioelectrical Impedance Analyzer (Tanita TBF-410). Waist circumference was measured at navel, with the participants standing. All measurements were performed with the participants wearing light clothes and without shoes. BMI was computed by dividing weight in kilograms by the square of height in meters. Venous blood was collected the next morning after an overnight fasting. Serum glucose was measured using the hexokinase glucose-6-phosphate dehydrogenase method (INTEGRA 800 system, Roche, USA).

Trained research dietitians interviewed each participant on demographic, lifestyle, diet, leisure time physical activity (LTPA), and medical history. Participants were identified as having a family history of diabetes if they reported one or more of their parents, grandparents, or siblings as having diabetes. Detailed diet was assessed through a 64-item food frequency questionnaire (FFQ), which had been validated in a subgroup of the present cohort [12], and the detail procedure of administering this FFQ had been reported previously [12]. Nutrients were calculated based on Taiwan’s Food Composition Table [13]. Heme iron content was reported previously [12]. Nutrients were calculated based on Taiwan’s Food Composition Table [13]. Heme iron content was estimated using the following percentages of total iron: 65% for beef and lamb, 39% for pork, 26% for chicken and fish [14]. Only those who completely avoid meat, fish, and all animal flesh for at least one year up until entry into the study were considered vegetarians. Current smoker is defined as the use of any cigarette in the past 6 months. Alcohol drinking habit is defined as drinking alcohol for at least once per week. The institutional review board at the Buddhist Dalin Tzu Chi Hospital approved the study, and all participants gave written informed consent.

Data are presented as either mean ± standard deviation or percent. IFG = impaired fasting glucose BMI = body mass index. LTPA = leisure time physical activity.

| Table 1. Characteristics of participants with normal glucose, impaired fasting glucose, and diabetes. |
|---------------------------------------------------------------|
| **Pre-menopausal women** | **Menopausal women** | **Men** |
| | Normal | IFG | Diabetes | P-value | Normal | IFG | Diabetes | P-value | Normal | IFG | Diabetes | P-value |
| n                  | 866  | 75  | 16       |        | 1382  | 285 | 122      |        | 1253  | 266 | 119      |        |
| Age (years)        | 45±6 | 47±5 | 48±4     | 0.0001 | 58±7  | 60±7 | 62±8     | <0.0001 | 54±10 | 58±9 | 59±8     | <0.0001 |
| BMI (kg/m²)        | 23±3 | 24±4 | 27±4     | <0.0001 | 23±3  | 25±3 | 25±4     | <0.0001 | 24±3  | 25±3 | 25±3     | <0.0001 |
| Waist (cm)         | 72±7 | 77±8 | 83±9     | <0.0001 | 74±7  | 79±9 | 80±8     | <0.0001 | 82±8  | 86±9 | 87±9     | <0.0001 |
| Body fat (%)       | 29±6 | 32±8 | 35±7     | <0.0001 | 29±6  | 31±7 | 32±7     | <0.0001 | 21±5  | 22±6 | 22±5     | 0.0004  |
| Family history of diabetes | 35% | 33% | 63% | 0.068 | 28% | 28% | 63% | <0.0001 | 24% | 27% | 58% | <0.0001 |
| Education          |       |      |          |        |       |      |          |        |       |      |          |        |
| Elementary or lower| 9%   | 12% | 44%     | <0.0001* | 39%   | 50% | 58%     | <0.0001 | 17%   | 23% | 16%     | 0.0093  |
| Secondary          | 65%  | 77% | 50%     |        | 46%   | 40% | 29%     |        | 48%   | 50% | 59%     |        |
| College or higher  | 26%  | 11% | 6%      |        | 15%   | 10% | 13%     |        | 35%   | 27% | 25%     |        |
| Smoking            |       |      |          |        |       |      |          |        |       |      |          |        |
| Current            | 0%   | 0%  | 0%      | 0.15*  | 0%    | 0%  | 0%      | 0.013*  | 4%    | 3%  | 5%      | 0.56    |
| Past               | 2%   | 0%  | 0%      |         | 1%    | 1%  | 0%      |         | 33%   | 29% | 36%     |         |
| Never              | 98%  | 100%| 100%    |         | 99%   | 98% | 100%    |         | 63%   | 67% | 59%     |         |
| Alcohol            |       |      |          |        |       |      |          |        |       |      |          |        |
| Current            | 1%   | 4%  | 0%      | 0.004*  | 1%    | 0%  | 0%      | 0.0042* | 8%    | 10% | 8%      | 0.69    |
| Past               | 1%   | 0%  | 6%      |         | 1%    | 1%  | 1%      |         | 23%   | 23% | 24%     |         |
| Never              | 97%  | 96% | 94%     |         | 98%   | 99% | 99%     |         | 70%   | 67% | 68%     |         |
| LTPA per week      |       |      |          |        |       |      |          |        |       |      |          |        |
| 0–30 minutes       | 49%  | 55% | 50%     | 0.0005* | 31%   | 33% | 22%     | 0.023   | 29%   | 29% | 29%     | 0.33    |
| 31–180 minutes     | 33%  | 31% | 31%     |         | 34%   | 32% | 28%     |         | 33%   | 28% | 28%     |         |
| >180 minutes       | 18%  | 15% | 19%     |         | 35%   | 35% | 50%     |         | 37%   | 42% | 43%     |         |
| Diet               |       |      |          |        |       |      |          |        |       |      |          |        |
| Vegetarian         | 37%  | 27% | 13%     | 0.0006* | 48%   | 39% | 18%     | <0.0001 | 23%   | 16% | 13%     | 0.0014  |
| Omnivore           | 63%  | 73% | 88%     |         | 52%   | 61% | 82%     |         | 77%   | 84% | 87%     |         |

Data are presented as either mean ± standard deviation or percent. IFG = impaired fasting glucose BMI = body mass index. LTPA = leisure time physical activity.

*Fisher’s exact test.

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Diabetes and Vegetarian Diet
Disease ascertainment

Potential cases of diabetes were initially identified using self-reported history of diabetes ascertained from the baseline medical history questionnaire or having a fasting plasma glucose $\geq 7.0$ mmol/L. Two physicians (HYH and MNL) subsequently confirmed the self-reported diabetes with the electronic medical records in Tzu Chi hospitals. For those who did not have medical records (28%), the physicians made telephone calls to confirm with the participants about their diabetes diagnosis. Participants who did not self-report a history of diabetes but had a fasting plasma glucose $\geq 7.0$ mmol/L were regarded as having diabetes if one of the following criteria was further confirmed in medical record or with the participants in a telephone follow-up: (1) physician diagnosis of diabetes; (2) prescription of diabetes medication; (3) an additional fasting plasma glucose $\geq 7.0$ mmol/L; (4) an additional HbA1C $\geq 6.5%$. Participants with one fasting plasma glucose $\geq 7.0$ mmol/L but subsequent check-up showing no diabetes were classified as having IFG. Participants with fasting plasma glucose $<5.6$ mmol/L and 5.6–6.9 mmol/L were classified as normal and IFG respectively [15]. For participants who self reported diabetes during baseline questionnaire interview, the duration of their diabetes (how many years they have known to have diabetes up until entry to the study) was asked.

Statistical analysis

After excluding 1377 non Tzu Chi commissioners, 35 participants who reported adopting vegetarian diet after diagnosis of diabetes, 10 participants with incomplete data on covariates, 267 participants with extreme average daily energy intakes (male: $>3.3$ MJ [800 kcal] or $>16.7$ MJ [4000 kcal], female: $<2.1$ MJ [500 kcal] or $>14.6$ MJ [3500 kcal]), and 13 participants whose diabetes status could not be confirmed (due to only one measurement of fasting blood glucose $\geq 7.0$ mmol/L), a total of 4384 participants were included in the present analysis. Demographic characteristics were compared using analysis of variance (continuous variables), or the Chi square test (categorical variables). Fisher’s exact test was applied for categorical variables with a cell number less than 5. Dietary intake was compared using Wilcoxon two-sample test. Polytomous logistic regression was used to compare the outcomes of IFG and diabetes with normal glucose as the reference group, with adjustment for age, family history of diabetes, education, LTPA, BMI, smoking (men only), and alcohol (men only). All analyses were completed using SAS 9.2.

Results

Table 1 shows the characteristics of participants with normal glucose, IFG, and diabetes. Diabetes individuals had the oldest

| Table 2. Crude prevalence of impaired glucose metabolism and other characteristics of vegetarians and omnivores. |
|---------------------------------------------------------------|
|                                                     | Pre-menopausal women | Menopausal women | Men |
|                                                     | Vegetarians | Omnivores | P-value | Vegetarians | Omnivores | P-value | Vegetarians | Omnivores | P-value |
| n                                                     | 343 | 614     |         | 792 | 997     |         | 349 | 1289 |
| Impaired glucose metabolism                             |             |         |         |             |         |         |             |         |         |
| Diabetes                                               | 0.6% | 2.3%   | 0.006* | 2.8% | 10%    | <0.0001 | 4.3% | 8.1%   | 0.0014 |
| Impaired fasting glucose                                | 5.8% | 9.0%   | 0.0071 | 14% | 18%    | 12% | 17% |
| Age (years)                                            | 46±5  | 45±6   | 0.023  | 59±8 | 58±7   | 0.25  | 55±9 | 55±10  | 0.14 |
| BMI (kg/m²)                                            | 23±3  | 23±3   | 0.023  | 23±3 | 24±3   | <0.0001 | 23±3 | 24±3   | <0.0001 |
| Waist (cm)                                             | 72±7  | 73±8   | 0.0083 | 75±8 | 76±8   | 0.0008 | 81±8 | 84±8   | <0.0001 |
| Body fat (%)                                           | 28±5  | 30±7   | <0.0001 | 28±6 | 31±6   | <0.0001 | 19±5 | 22±5   | <0.0001 |
| Education                                              |         |         |         |         |         |         |         |         |
| Elementary or lower                                     | 10%  | 10%    | 0.90   | 44% | 41%    | 0.35  | 19%  | 17%    | 0.65 |
| Secondary                                              | 67%  | 65%    | 0.023  | 42% | 45%    | 0.0071 | 50%  | 49%    |
| College or higher                                       | 24%  | 25%    | 0.023  | 14% | 14%    | 0.31  | 31%  | 34%    |
| Family history of diabetes                              | 34%  | 36%    | 0.50   | 27% | 33%    | 0.0097 | 28%  | 27%    | 0.85 |
| Smoking                                                |         |         |         |         |         |         |         |         |
| Current                                                | 0%   | 0.5%   | 0.043* | 0% | 0%     | 0.09* | 0%   | 5%    | <0.0001* |
| Past                                                   | 2%   | 1.5%   |         | 1% | 1%     | 0.09* | 1%   | 31%   | 0.33 |
| Never                                                  | 98%  | 98%    | 0.0083 | 99% | 99%    | 0.0083 | 69%  | 62%    |
| Alcohol                                                |         |         |         |         |         |         |         |         |
| Current                                                | 1%   | 2%     | 0.012* | 1% | 1%     | 0.025* | 1%   | 10%   | <0.0001* |
| Past                                                   | 1%   | 1%     |         | 1% | 1%     | 2.6%  | 26%  | 22%    |
| Never                                                  | 98%  | 97%    | 0.0083 | 98% | 98%    | 0.0083 | 72%  | 68%    |
| LTPA per week                                          |         |         |         |         |         |         |         |         |
| 0–30 min                                               | 51%  | 49%    | 0.65   | 33% | 28%    | 0.057 | 32%  | 29%    | 0.037 |
| 31–180 min                                             | 31%  | 33%    | 9%     | 32% | 35%    | 35%   | 31%  | 31%    |
| >180 min                                               | 19%  | 17%    | 9%     | 34% | 37%    | 33%   | 40%  |        |

Data are presented as either mean ± standard deviation or percent. BMI = body mass index. LTPA = leisure time physical activity.

*Fisher’s exact test.

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| Nutrient | Pre-menopausal women | Menopausal women | Men | Vegetarians | Omnivores | P-value | Vegetarians | Omnivores | P-value | Vegetarians | Omnivores | P-value |
|----------|----------------------|------------------|----|-------------|-----------|---------|-------------|-----------|---------|-------------|-----------|---------|
| Energy (kcal) | 54.1 (9.16) | 5.67 | 6.15 | 6.15 | 6.15 | <0.001 | 9.04 | 6.86 | 6.17 | <0.001 | 9.04 | 6.86 | 6.17 | <0.001 |
| Protein (% energy) | 12 | 11.3 | 13 | 12.15 | 12 | 11.3 | 12 | 12.15 | 12 | 11.3 | 12 | 12.15 | 12 | 11.3 | <0.001 |
| Animal protein (g) | 3.3 | 3.9 | 3.5 | 3.4 | 2.5 | 3.4 | 3.4 | 2.5 | 3.4 | 3.4 | 2.5 | 3.4 | 3.4 | <0.001 |
| Plant protein (g) | 9.6 | 12.6 | 11.2 | 10.8 | 10.8 | 10.8 | 10.8 | 10.8 | 10.8 | 10.8 | 10.8 | 10.8 | <0.001 |
| Fat (% energy) | 26 | 23.2 | 29 | 24.3 | 24 | 21.3 | 24 | 21.3 | 24 | 21.3 | 24 | 21.3 | 24 | 21.3 | <0.001 |
| SFA (g) | 9 | 7.9 | 10 | 8.7 | 8.7 | 8.7 | 8.7 | 8.7 | 8.7 | 8.7 | 8.7 | 8.7 | 8.7 | <0.001 |
| MUFA (g) | 12 | 10 | 9 | 7.8 | 7.8 | 7.8 | 7.8 | 7.8 | 7.8 | 7.8 | 7.8 | 7.8 | 7.8 | <0.001 |
| PUFA (g) | 13 | 9.7 | 14 | 10.2 | 10.2 | 10.2 | 10.2 | 10.2 | 10.2 | 10.2 | 10.2 | 10.2 | 10.2 | <0.001 |
| Carbohydrate (% energy) | 63 | 57.67 | 59 | 53.65 | 65 | 60.7 | 62 | 56.67 | 65 | 60.7 | 62 | 56.67 | 65 | 60.7 | <0.001 |
| Dietary fiber (g) | 23 | 17.3 | 19 | 14.2 | 19 | 14.2 | 19 | 14.2 | 19 | 14.2 | 19 | 14.2 | 19 | 14.2 | <0.001 |
| Starch (g) | 98 | 39.15 | 15 | 48.2 | 19 | 48.2 | 19 | 48.2 | 19 | 48.2 | 19 | 48.2 | 19 | 48.2 | <0.001 |
| Potassium (g) | 2.2 | 1.6 | 2.2 | 1.6 | 2.2 | 1.6 | 2.2 | 1.6 | 2.2 | 1.6 | 2.2 | 1.6 | 2.2 | <0.001 |
| Iron (mg) | 10 | 6.1 | 11 | 5.7 | 11 | 5.7 | 11 | 5.7 | 11 | 5.7 | 11 | 5.7 | 11 | 5.7 | <0.001 |
| Zinc (mg) | 2.1 | 1.6 | 2.1 | 1.6 | 2.1 | 1.6 | 2.1 | 1.6 | 2.1 | 1.6 | 2.1 | 1.6 | 2.1 | <0.001 |
| Riboflavin (mg) | 13 | 9.2 | 10 | 6.1 | 11 | 5.7 | 11 | 5.7 | 11 | 5.7 | 11 | 5.7 | 11 | 5.7 | <0.001 |
| Niacin (mg) | 13 | 9.2 | 10 | 6.1 | 11 | 5.7 | 11 | 5.7 | 11 | 5.7 | 11 | 5.7 | 11 | 5.7 | <0.001 |
| Folic acid (mcg) | 38 | 28.0 | 38 | 25.0 | 38 | 28.0 | 38 | 25.0 | 38 | 28.0 | 38 | 25.0 | 38 | 28.0 | <0.001 |
| Vitamin B12 (mcg) | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | <0.001 |
| Vitamin C (mg) | 2.6 | 2.0 | 2.6 | 2.0 | 2.6 | 2.0 | 2.6 | 2.0 | 2.6 | 2.0 | 2.6 | 2.0 | 2.6 | <0.001 |
| Vitamin E (mg) | 1.1 | 0.4 | 1.1 | 0.4 | 1.1 | 0.4 | 1.1 | 0.4 | 1.1 | 0.4 | 1.1 | 0.4 | 1.1 | <0.001 |
| Vitamin K (mcg) | 2.0 | 1.4 | 2.0 | 1.4 | 2.0 | 1.4 | 2.0 | 1.4 | 2.0 | 1.4 | 2.0 | 1.4 | 2.0 | <0.001 |
| Fish (g) | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | <0.001 |
| Meat (g) | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | <0.001 |
| Dairy products (g) | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | <0.001 |
| Total vegetables (g) | 104 | 53.6 | 104 | 53.6 | 104 | 53.6 | 104 | 53.6 | 104 | 53.6 | 104 | 53.6 | 104 | 53.6 | <0.001 |
Table 2 shows the crude prevalence of diabetes, IFG, and other characteristics of vegetarians and omnivores. Vegetarians had lower prevalence of diabetes and IFG than omnivores. All groups had average BMI ≤25 kg/m², and had lower average waist circumference than recommended for Asians (men: <90 cm, and women <80 cm) [16]. Among men, vegetarians were less likely to ever use alcohol or tobacco.

Overall, our study participants consumed a predominantly plant-based diet such that even the omnivores consumed little meat and fish (Table 3). Men consumed significantly more energy and most nutrients (except for calcium, folate, and vitamin C) than women. Vegetarians had a higher percent of energy intake as carbohydrate, and lower percent as fat and protein, while having higher intake of fiber, calcium, magnesium, non-heme iron, folate, vitamin A, and lower intake of saturated fat, cholesterol, and vitamin B12. Vegetarians also consumed more soy products, total and green leafy vegetables, nuts, whole grains; less tea; and a similar amount of dairy products and fruits, compared with omnivores. The majority (72% of men and 82% of women) did not report consumption of any sweetened beverage in the FFQ.

Vegetarian diet is negatively associated with both IFG and diabetes in men, pre-menopausal, and menopausal women (Table 4). The protective association for diabetes is even stronger without controlling for BMI in men (OR: 0.43, 95% CI: 0.24–0.77), in pre-menopausal women (OR: 0.21, 95% CI: 0.05–0.97), and in menopausal women (OR: 0.23, 95% CI: 0.14–0.37). This association in pre-menopausal women was no longer statistical significant after adjusting for BMI as there were only 16 cases of diabetes in this group. BMI is highly correlated with waist circumference (the correlation coefficients r for male: 0.84, female: 0.74) and body fat (r for male: 0.76, female: 0.84). When either waist circumference or body fat was adjusted instead of BMI, similar results were found (data not shown). Family history of diabetes is significantly associated with diabetes but not with IFG. In men, current smoker (versus never smoker) is associated with diabetes, though not significant due to a low number of current smokers. In women, higher education (versus elementary school) is negatively associated with diabetes.

As diabetes patients are often advised to change diet and lifestyle, we conducted a sensitivity analysis excluding those who self reported history of diabetes at baseline (n = 216), and counted only diabetes cases that were newly detected in this present study (n = 41). We found a similar protective association between vegetarian diet and diabetes in menopausal women (OR: 0.34, 95% CI: 0.12–0.95). The results were insignificant in men and pre-menopausal women due to limited number of cases of new diabetes.

Discussion

In this Buddhist population consuming a plant-based diet with little meat and fish, true vegetarians who completely avoid animal flesh, while eating more soy, vegetables, nuts and whole grain, have lower odds for IFG and diabetes, after accounting for various confounders, risk factors, and BMI. The protective association is consistent in men and women although the association in pre-menopausal women was not significant due to a small number of diabetes cases.
Our result is consistent with the Adventist Health Study 2 (AHS-2), which found lower prevalence [3] and incidence [4] of diabetes in vegetarians. Similar to AHS-2 [17], we found vegetarians consumed a higher percentage of energy as carbohydrate, a lower percentage as fat and protein, and higher levels of plant protein, fiber, iron, and magnesium compared with omnivores in respective studies. We did not analyze subtypes of vegetarians (vegan, lacto-ovo-, or pesco-), as the AHS-2 did, since most of our vegetarians were of lacto-ovo type, with a small number of vegans (n = 69), and there were no cases of diabetes found within the vegan group. Consumption of eggs and dairy, however, was low, suggesting that the vegetarian diet in our population may resemble that of a vegan diet more than a typical Western lacto-ovo vegetarian diet when compared with AHS-2 [17] and EPIC-Oxford [18].

Despite similar or higher energy consumption, our vegetarians had lower BMI than omnivores. A similar finding is also observed in AHS-2 [3,17]. Energy content of foods estimated by Atwater factors (for food composition tables and food labels) may not accurately reflect the actual energy utilized by the body due to the complexity in human digestion, and the variation in bioavailability as influenced by cooking and food processing methods, cell wall structures, and microbiome of the individual intestinal track [19–21].

The association between meat and diabetes has been reported recently in a large prospective study of European adults and a previous meta-analysis of prospective cohorts [22,23], but not in a Shanghai study [24]. Although the Shanghaiese population has a more similar ethnicity, the diabetes ascertainment depended on self-reported data; this could be a limitation for caution because the percent of undiagnosed diabetes (64% in urban China, 2000 to 2001) [25] is much higher than most Western countries (29% for the US, NHANES 1999–2000) [26]. Heme iron in meat had been suggested as a potential mediator leading to diabetes, as iron overload produces oxidative stress and induces insulin resistance [27,28]. Although vegetarians had higher iron intake in both our study and in AHS-2, the iron is of non-heme form, which is absorbed to a lesser degree than that of heme iron from meat [29].

The higher intake of green leafy vegetables and magnesium may potentially contribute to the protective association between vegetarian diet and diabetes. Studies suggest that consuming more leafy green vegetables and a greater variety of fruits and vegetable are associated lower risk of diabetes in Europeans [30,31]. A dietary pattern characterized by fruits, vegetables, and soy has also been associated with lower risk of diabetes in non-smoking Chinese [32]. A meta-analysis found magnesium to be protective of diabetes, and suggested that magnesium deficiency may induce insulin resistance [33].

### Strength and limitation

While our findings suggest a negative association between a vegetarian diet and diabetes/IFG, the temporal association is unclear due to the cross-sectional nature of the study. Although we have accounted for several confounders in our models, it is likely that other residual confounders still remain. The null association between LTPA and diabetes may have been influenced by reverse causation, as diabetes individuals may have increased physical activities in order to manage their disease. The measurements of body fat by Bioelectrical Impedance Analysis should be interpreted with caution as it has a poor accuracy for estimating absolute body composition [34].

The current study also has several strengths. The questionnaires were interviewed instead of self-administered – this enabled us to clarify questions, engage participants, and minimize potential

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**Table 4. Polytomous logistic regression analysis of the association between diet and impaired glucose metabolism.**

|                     | IFG | 95% CI | Diabetes | IFG | 95% CI | Diabetes | IFG | 95% CI | Diabetes | IFG | 95% CI | Diabetes |
|---------------------|-----|--------|----------|-----|--------|----------|-----|--------|----------|-----|--------|----------|
| **Age**             | 1.05| 1.03, 1.06 | 1.08     | 1.05 | 1.10   | 1.04, 1.16 | 1.08 | 0.96 | 1.22, 1.03 | 1.01 | 1.05 | 1.08   |
| **BMI**             | 1.12 | 1.07, 1.17 | 1.14     | 1.07 | 1.22   | 1.05, 1.20 | 1.25 | 1.11 | 1.42, 1.14 | 1.10 | 1.19 | 1.13   |
| **Family history of diabetes vs none** | 1.29 | 0.94, 1.76 | 5.15     | 3.42 | 7.75   | 0.92 | 0.55, 1.54 | 3.54 | 1.20, 10.44 | 1.01 | 0.75, 1.36 | 5.19   |
| **Vegetarian vs omnivorous diet** | 0.66 | 0.46, 0.95 | 0.49 | 0.28, 0.89 | 0.60 | 0.35, 1.04 | 0.26 | 0.06 | 1.21, 0.73 | 0.56 | 0.95, 0.25 | 0.15, 0.42 |
| **Education**       | 1.06 | 0.73, 1.53 | 1.65     | 0.93, 2.93 | 1.42 | 0.65, 3.11 | 0.26 | 0.08 | 0.84, 0.88 | 0.66, 1.19 | 0.56 | 0.35, 0.89 |
| **LTPA per week**   | 0.87 | 0.58, 1.32 | 1.15     | 0.60, 2.19 | 0.60 | 0.21, 1.67 | 0.10 | 0.01 | 0.89, 0.68 | 0.43, 1.07 | 0.65 | 0.35, 1.22 |
| **Past smokers vs never** | 0.67 | 0.31, 1.43 | 1.36     | 0.52, 3.52 | -     | -     | -     | -     | -     | -     | -     |
| **Current smokers vs never** | 0.71 | 0.51, 0.99 | 1.01 | 0.64, 1.60 | -     | -     | -     | -     | -     | -     | -     |

**IFG = impaired fasting glucose. OR = odds ratio. BMI = body mass index. LTPA = leisure time physical activity.**

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