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Meal-specific food patterns and the incidence of hyperglycemia in a Chinese adult population

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Abstract

This study aimed to examine the association between meal-specific food patterns and incident hyperglycaemia in a Chinese adult population. Adults aged 20 years and older (*n* 1056) were followed from 2002 to 2007. Dietary data were collected using a 3-d food record and meal-specific (breakfast, lunch and dinner) food patterns were independently described by factor analysis based on the consumption of thirty-five food groups at each eating occasion. Each food pattern score was recoded as quartiles. Hyperglycaemia was defined as fasting plasma glucose >5·6 mmol/l at baseline and follow-up. The associated between food patterns and incident hyperglycaemia was assessed by logistic regression. During the follow-up, 125 new cases of hyperglycaemia were identified. Traditional (wheat) breakfast was inversely associated with incident hyperglycaemia, whereas traditional (rice, vegetable and pork) lunch and dinner were positively associated with the risk of incident hyperglycaemia, even after adjustment for a number of covariates including glycaemic load, carbohydrate intake and BMI. Incident hyperglycaemia occurred in 15·9, 13·6, 11·7, 6·1 % across quartiles of traditional breakfast; and 5·3, 9·1, 15·9, 17·1 % of the quartiles of traditional lunch pattern. The adjusted OR for hyperglycaemia was 0·67 (95 % CI 0·48, 0·92), 1·83 (95 % CI 1·32, 2·53) and 1·39 (95 % CI 1·04, 1·86) for 1 SD increase of traditional breakfast, lunch and dinner pattern factor score, respectively. A traditional wheat-based breakfast is associated with a decreased risk of hyperglycaemia. A rice-based traditional lunch and dinner is associated with an increased risk of hyperglycaemia in Chinese adults.

Key words: Chrono-nutrition dietary patterns: Hyperglycaemia: Chinese adults: Cohort studies

Over the past three decades China has been experiencing a rapid increase in the prevalence of type 2 diabetes[1]. In 2002, the prevalence of type 2 diabetes was 13·1 % for urban inhabitants aged 60 years and older[2]. Recent data suggested that China has the largest number of people with type 2 diabetes in the world[3]. Diet can influence glucose homoeostasis and modification of diet can have beneficial effects on diabetes risk[4]. Excessive energy intake is the main driver with glycaemic load as an additional factor. However, the majority of the evidence of these effects is based on data from western countries, with only limited data available relating to diet and diabetes in the Chinese population[5–10], and most of the studies focused on individual foods or nutrients.

There is a growing interest in the relationship between dietary patterns derived by factor analysis and chronic disease[11,12]. A food pattern rich in fruits and vegetable is often found to be inversely associated with the risk of diabetes, and the opposite association is found between a Western dietary pattern (high consumption of red meat and processed food) and type 2 diabetes[13–17]. These findings were mainly observed in Western countries, but also in Japan[18]. One previous cross-sectional study from China has shown associations between dietary patterns and type 2 diabetes[19], but prospective studies of the association between dietary patterns and incident type 2 diabetes are limited in China.

Furthermore, most of the dietary pattern studies focus on the overall dietary intake without differentiating eating occasions. There are only a limited number of studies examining meal-specific dietary patterns, often focussing on specific meals[20–22]. No prospective studies have assessed the association between meal-specific dietary patterns and diabetes. This may be partly due to the fact that most of the large cohort studies use FFQ to estimate the intake of food, and therefore do not measure meal-specific consumption.

Accumulating evidence suggests the importance of time of eating[23,24]. In animals and humans, the timing of nutrient intake plays an important role in regulating the circadian clock[25]. It has been found that high fat intake changes the

Abbreviation: FPG, fasting plasma glucose.

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expression of the clock gene and disrupts the circadian clock in mice[26]. There is also a circadian rhythm that influences the response to food intake. The response to food intake differs between morning and evening. Gastric emptying and nutrient absorption from the gut are higher during the day than at night[27]. In animal models, compared with early high fat consumption, mice fed a high-fat meal later in the day had a higher weight gain and blood glucose concentration compared with mice fed a high-fat meal earlier in the day, despite the same total fat and energy intake[28].

Consistent with findings from animal models, the importance of timing of food intake is suggested in human population studies. For example, in the 1946 British birth cohort study, higher energy intake at breakfast was associated with lower hypertension prevalence 10 years later[29]. In the same study, increasing carbohydrate intake in the morning while reducing fat intake is inversely associated with the development of the metabolic syndrome[30].

Using 5-year longitudinal data from the Jiangsu Nutrition Study, the aim of this study was to assess the association between baseline meal-specific dietary patterns and incident hyperglycaemia among Chinese adults.

Methods

Subjects

The Jiangsu Nutrition cohort study is of persons aged 20 years or older and the methods of sampling have been described previously[31,32]. In 2002, 2849 adults aged 20 years and above living in two cities and six rural areas in a central eastern China coastal province had fasting blood samples measured for glucose, and provided dietary information. In 2007, only 1682 participants could be identified; 1492 of them participated in the study, and 1175 of them had fasting blood samples measured. For the current analysis, we included study participants measured at both time points with a fasting plasma glucose (FPG) <5·6 mmol/l in 2002 and without known diabetes. The final sample in the study consists of 445 men and 611 women (*n* 1056). The study was approved by the institutional ethics committee of the Jiangsu Provincial Center for Disease Control and Prevention.

Compared with the retained participants, those lost to follow-up were generally younger (mean age in 2002 45·5 *v.* 49·3 years, $P<0·05$). No differences in mean BMI, waist circumference (WC), glucose and energy intake at baseline were found ($P>0·05$).

Data collection and measurements

Participants were interviewed at their homes by health workers using a standard questionnaire[33].

Baseline dietary intake

Exposure variable – meal-specific dietary patterns. Food intake was assessed using a 3-d weighed food diary (including 1 weekend day). Eating occasions were pre-coded in the food diary as: (1) breakfast; (2) snack in the morning; (3) lunch; (4) snack in the afternoon; (5) dinner; (6) snack at night. Food intakes at any of the three main meals were categorised into thirty-five food groups based on the similarity of nutrient profiles in order to conduct dietary pattern analysis. Nutrient intake was calculated using the Chinese Food Composition Table[34]. Participants were also asked about their usual number of meals per day by the question 'How many meals do you usually have each day?'. To minimise misreporting of energy intake, health workers clarified any intake value for a particular food that fell below or above the usual value reportedly consumed by the population within the region.

Meal-specific dietary patterns (the main independent variable) were identified by factor analysis, using a standard principal component analysis method. We used the estimated intake of thirty-five food groups (g/d) at each meal as input variables in factor analyses. Factors were rotated with an orthogonal (varimax) rotation to improve interpretability and minimise the correlation between the factors. The number of factors retained from each dietary pattern classification method was determined by eigenvalue (>1), scree plot and factor interpretability. Labelling of the factors was primarily descriptive and based on our interpretation of the pattern structures.

Factor loadings are analogous to simple correlation between the food items and the factor. Higher loadings (absolute value) indicate that the food shares more variance with that factor. The sign of the loading determines the direction of the correlation of each food to the factor.

Participants were assigned pattern-specific factor scores for each meal (breakfast, lunch and dinner). Scores for each pattern were calculated as the sum of the products of the factor loading coefficients and standardised daily intake of the food consumed at the relevant meal associated with that pattern.

Outcome variables

A morning blood sample was collected after an overnight fast from all study participants. FPG was measured using an enzymatic (hexokinase) colorimetric test. We defined diabetes as FPG >7·0 mmol/l or having known diabetes (self-reported doctor diagnosed), and hyperglycaemia as FPG >5·6 mmol/l[35].

Anthropometric measurements. In both 2002 and 2007, anthropometric measurements were obtained using standard protocols and techniques. Body weight was measured in light indoor clothing without shoes to the nearest 100 g. Height was measured without shoes to the nearest mm using a stadiometer. Overweight was defined as BMI ≥24 kg/m^2[36]. WC was measured to the nearest millimetre midway between the inferior margin of the last rib and the crest of the ilium, in the mid-axillary line in a horizontal plane. Central obesity was defined as WC ≥90 cm in men or ≥80 cm in women. Blood pressure was measured twice by mercury sphygmomanometer on the right upper arm of the subject, who was seated for 5 min before the measurement. The mean of these two measurements was used in the analyses. Hypertension was defined as systolic blood pressure above 140 mmHg and/or diastolic blood pressure above 90 mmHg, or using antihypertensive drugs.

Other covariates. Current cigarette smoking was assessed by asking the frequency of daily cigarette smoking. Alcohol consumption was assessed by asking the frequency and amount of alcoholic beverage consumed. Active commuting (walking or cycling to and from work) was categorised into three groups: none, 1–30 min/d and >30 min/d. Education was recoded into either 'low' (illiteracy, primary school); 'medium' (junior middle school); or 'high' (high middle school or higher), based on six categories of education levels in the questionnaire. Occupation was recoded into 'manual' or 'non-manual' based on a question with twelve occupational categories. Information on household income was also asked and was categorised into 'low'; 'medium'; or 'high'. Family history of diabetes was defined as the presence of known family members with diabetes in any of three generations (siblings, parents or grandparents). Diabetes medication was assessed among participants who reported having diabetes in order to identify any cases of misreporting.

Statistical analyses

Dietary pattern scores at each meal were recoded into quartiles. The χ^2 test was used to compare difference between categorical variables, and ANOVA was used to compare differences in continuous variables between groups. Multilevel logistic regression was used to determine the association between dietary patterns (quartiles) and incident hyperglycaemia adjusted for age, education, occupation, active commuting, smoking, passive smoking, alcohol drinking, overweight (yes/no) at baseline, central obesity, family history of diabetes, energy intake. These multivariable models were adjusted for household clustering using the xtmelogit command in STATA. In sensitivity analyses, the association between dietary patterns and hyperglycaemia was adjusted for glycaemic load or total carbohydrate intake or change in physical activity level during follow-up. The associations between glycaemic load, energy intake at breakfast, meal-specific rice intake and hyperglycaemia were also assessed using multilevel logistic regressions. All the analyses were performed using STATA 14 (Stata Corporation).

Table 1. Baseline sample characteristics by incident hyperglycaemia status (Mean values and standard deviations; percentages)

	Hyperglycaemia				
	No		Yes		
	Mean	SD	Mean	SD	*P*
n	931		125		
Age (years)	48·2	13·3	52·0	12·0	0·003
Energy intake (kJ/d)	8329·5	3279·0	8727·8	3530·8	0·21
Energy intake (kcal/d)	1990·8	783·7	2086·0	843·9	0·21
Fat (g/d)	81·9	36·5	81·0	32·2	0·79
Carbohydrate (g/d)	321·8	97·4	315·7	99·0	0·51
Protein (g/d)	71·7	20·9	76·0	24·9	0·035
Fat intake (% energy)	31·3	9·0	31·7	8·7	0·58
BMI (kg/m^2)	23·1	3·3	24·5	3·4	<0·001
BMI status (%)					0·001
<24 kg/m^2	62·7		51·2		
24–27·9 kg/m^2	29·1		31·2		
≥28 kg/m^2	8·2		17·6		
Men (%)	40·8		52·0		0·017
Manual job (%)	52·6		43·2		0·048
Education (%)					0·85
Low	52·5		54·4		
Medium	36·2		33·6		
High	11·3		12·0		
Leisure time physical activity (%)					0·007
None	93·1		85·6		
1–30 min/d	3·4		8·8		
>30 min/d	3·4		5·6		
Sedentary activity (%)					0·19
<1 h	16·8		11·2		
1–2 h	31·3		29·6		
>2 h/d	52		59·2		
Active commuting (%)					0·90
None	40·7		42·4		
1–30 min/d	47·7		47·2		
>30 min/d	11·6		10·4		
Smoker (%)	26·6		35·2		0·044
Alcohol drinking (%)	25·7		24·8		0·83
Hypertension	28·6		37·6		0·038
Central obesity (%)	27·6		40·0		0·004
Weight change (%)					0·017
Lose up to 5 %	13·5		22·0		
Maintain	58·7		58·5		
Gain 5 % or more	27·8		19·5		

Results

During the follow-up 125 new cases of hyperglycaemia were identified, among them thirty-five were cases of diabetes (FPG >7 mmol/l, or taking medication, or having known diabetes) and eight participants started taking diabetic medication following on from the survey examination. Those who developed hyperglycaemia were older and had higher BMI and protein intake at baseline than those who did not developed the condition (Table 1).

Most of the participants (98·5 %) reported having three meals per day. Only 15 (1·4 %) reported having two meals a day. At each eating occasion, two dietary patterns (traditional and modern) were identified (Table 2). A traditional wheat-based pattern at breakfast was characterised by high intake of wheat (e.g. steamed buns, *Mantou* in Chinese) (factor loading 0·81), fresh vegetable and tofu but a low intake of rice (factor loading −0·57) and salted vegetables. A modern breakfast pattern had high intake of eggs, milk, cake, soyamilk and deep fried products (e.g. *Youtiao*). The dietary patterns identified were similar for lunch and dinner. A traditional lunch or dinner pattern had high intake of rice, fresh vegetables, fish and pork. Modern lunch or dinner patterns had high loadings of beer, beverage and lamb. Among all the factor loadings of all the traditional dietary patterns, the highest absolute values are rice and wheat. For modern lunch and dinner patterns, rice and wheat are not the main contributors. The correlation coefficient between traditional breakfast pattern and traditional lunch or dinner was −0·45 and −0·62, respectively.

The online Supplementary Tables S1(a) (b) show the baseline sample characteristics across quartiles of traditional meal patterns.

Traditional (wheat) breakfast was inversely related but traditional (rice, vegetable and pork) lunch and dinner were positively associated with the risk of incident hyperglycaemia, even after adjustment for a number of covariates. The prevalence of incident

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Table 2. Factor loadings of meal-specific dietary patterns

	Breakfast		Lunch		Dinner	
	Factor 1 (traditional)	Factor 2 (modern)	Factor 1 (traditional)	Factor 2 (modern)	Factor 1 (traditional)	Factor 2 (modern)
Rice	−0·57	−0·61	0·77	−0·14	0·85	−0·05
Wheat	0·81	0·10	−0·74	0·02	−0·80	−0·10
Deep fried products	−0·02	0·34	−0·09	0·00	−0·10	0·03
Whole grain	0·25	0·03	−0·13	−0·05	−0·29	0·01
Tofu	0·42	−0·06	0·03	−0·04	0·06	0·09
Dry tofu	0·14	−0·08	0·20	−0·01	−0·01	0·16
Soya milk	−0·09	0·38	−0·18	0·02	−0·16	0·04
Legume	0·16	0·00	0·12	0·02	0·05	0·14
Fresh bean	0·36	−0·25	0·03	−0·16	0·12	−0·29
Tubers	0·32	−0·10	0·07	−0·01	−0·03	0·01
Fresh vegetable	0·46	−0·12	0·55	−0·01	0·59	0·17
Salted vegetable	−0·34	−0·51	0·08	−0·06	−0·07	−0·27
Fungus	−0·02	0·02	0·18	0·09	0·28	0·19
Melon	0·32	−0·08	−0·29	−0·02	−0·02	−0·12
Fruit	0·07	−0·04	−0·21	0·04	−0·08	0·14
Nuts	−0·01	−0·11	−0·13	0·19	−0·03	0·18
Pork	0·16	0·20	0·41	0·06	0·48	0·09
Beef	−0·05	0·16	0·05	0·12	0·04	0·46
Lamb	−0·02	0·09	−0·09	0·46	−0·08	0·49
Poultry	0·08	−0·05	0·18	0·20	0·32	0·21
Offal	0·02	−0·02	0·09	0·26	0·04	0·36
Milk	−0·14	0·43	0·01	−0·01	−0·04	0·33
Milk powder	−0·04	0·21	−0·12	0·08	−0·11	0·11
Yogurt	−0·04	0·12	0·00	−0·02	−0·01	−0·05
Eggs	−0·04	0·46	0·01	0·01	0·13	−0·08
Fish	0·01	−0·10	0·36	0·16	0·36	0·14
Shrimp	−0·04	−0·07	0·17	0·52	0·28	0·18
Cake	−0·19	0·41	−0·12	0·17	−0·09	0·08
Beverage	0·02	0·04	0·01	0·36	−0·01	0·34
Spirit	0·05	0·01	0·06	0·24	0·03	0·10
Beer	0·17	−0·04	−0·07	0·64	−0·02	0·42
Wine	−0·03	0·06	0·09	0·00	0·13	0·14
Sugar	−0·02	0·06	−0·11	−0·06	−0·10	0·11
Bean thread noodle	0·27	−0·03	−0·12	0·08	−0·05	0·19
Others	−0·09	−0·02	0·03	0·53	0·08	0·13
Variance explained (%)	6·3	4·8	6·3	4·7	7·6	4·2

Table 3. Incident hyperglycaemia associated with eating occasion-specific dietary pattern scores in the Jiangsu Nutrition Study
(Odds ratios and 95 % confidence intervals)

	Model 1*			Model 2†			Model 3‡			Model 4§		
	OR	95 % CI	*P*	OR	95 % CI	*P*	OR	95 % CI	*P*	OR	95 % CI	*P*
Breakfast												
Traditional pattern	0·61	0·45, 0·82	0·001	0·67	0·48, 0·92	0·013	0·67	0·48, 0·93	0·016	0·73	0·58, 0·91	0·006
Modern pattern	1·15	0·90, 1·47	0·264	1·03	0·79, 1·33	0·824	1·04	0·80, 1·35	0·773	1·10	0·87, 1·37	0·832
Lunch												
Traditional pattern	1·89	1·38, 2·60	<0·001	1·83	1·32, 2·53	<0·001	1·78	1·29, 2·47	0·001	1·66	1·31, 2·09	<0·001
Modern pattern	0·97	0·79, 1·20	0·800	0·95	0·77, 1·17	0·645	0·96	0·78, 1·18	0·683	1·05	0·86, 1·28	0·814
Dinner												
Traditional pattern	1·40	1·08, 1·81	0·011	1·39	1·04, 1·86	0·027	1·37	1·02, 1·83	0·036	1·38	1·10, 1·73	0·005
Modern pattern	1·18	0·95, 1·47	0·143	1·13	0·89, 1·43	0·308	1·13	0·89, 1·43	0·315	1·08	0·88, 1·34	0·456

* Model 1: age, sex, total energy intake.
† Model 2: further adjusted for BMI, central obesity, anaemia, hypertension, smoking, alcohol drinking, family history of diabetes, income, education, residence (urban/rural), job (manual/non-manual), sedentary activity, active commuting and leisure time physical activity.
‡ Model 3: further adjusted for weight change (lose >5 % body weight, maintained, gain >5 %).
§ Model 4: model 2 + mutual adjustment for other dietary pattern in the same eating occasion.

hyperglycaemia was 15·9, 13·6, 11·7, 6·1 % across quartiles of traditional breakfast; 5·3, 9·1, 15·9, 17·1 % across quartiles of traditional lunch pattern. The adjusted OR for hyperglycaemia was 0·67 (95 % CI 0·48, 0·92), 1·83 (95 % CI 1·32, 2·53) and 1·39 (95 % CI 1·04–1·86) for one unit increase of traditional breakfast, lunch and dinner pattern factor score, respectively (Table 3). There was no association between incident hyperglycaemia and either modern breakfast (egg, cake and milk), modern lunch (meat and alcohol) or modern dinner patterns. The above associations did not change after further adjustment for weight change during

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follow-up (model 3, Table 3). Total carbohydrate intake was not associated with hyperglycaemia (data not shown). Glycaemic load was positively associated with incident hyperglycaemia after adjusting for age, sex and energy intake. Comparing extreme quartiles of glycaemic load, the OR for incident hyperglycaemia was 2·00 (95 % CI 1·02, 3·92). After further adjustment for other covariates, including dietary patterns, the association between glycaemic load and hyperglycaemia became non-significant. However, the observed associations between dietary patterns and hyperglycaemia were independent of total carbohydrate intake, and glycaemic load (data not shown). In the sample, 69 (6·5 %) reported a decrease, whereas 46 (4·4 %) reported an increase in their leisure time physical activity level. Adjusting for the change in physical activity levels did not change the above association between the meal-specific dietary patterns and incident hyperglycaemia (data not shown).

Energy intake at breakfast was inversely associated with incident hyperglycaemia. After adjusting for age, sex and total daily energy intake, every 418 kJ (100 kcal) of energy intake at breakfast was associated with an 11 % lower risk of having incident hyperglycaemia (OR 0·89; 95 % CI 0·81, 0·99). However, there was no association between energy intake at lunch or dinner and incident hyperglycaemia.

There were thirty-five incident diabetes cases. After adjusting for age, sex and total energy intake, for one unit change of dietary pattern scores, the OR for incident diabetes was 0·66 (95 % CI 0·47, 0·92) for traditional breakfast, 1·54 (95 % CI 1·08, 2·17) for traditional lunch and 1·55 (95 % CI 1·10, 2·18) for traditional dinner, respectively.

In sensitivity analyses, we also assessed the association between meal-specific rice intake and incident hyperglycaemia. After adjusting for age, sex and energy intake, compared with rice intake <50 g, the OR for hyperglycaemia for rice intake of 50–100, 100–150, >150 g at dinner were 1·90 (95 % CI 0·95, 3·80), 2·62 (95 % CI 1·34, 5·09) and 2·56 (95 % CI 1·08, 6·06), respectively; and, for the same lunch rice intake categories, 0·88 (95 % CI 0·41, 1·87), 1·72 (95 % CI 0·85, 3·45) and 1·72 (95 % CI 0·75, 3·94), respectively.

Discussion

In this prospective population-based study we found that a traditional wheat-based breakfast was inversely associated with the risk of incident hyperglycaemia over 5 years of follow-up independent of glycaemic load and BMI. A rice-based traditional lunch and dinner was positively associated with incident hyperglycaemia.

To the best of our knowledge, this is the first study assessing the association between meal-specific dietary patterns and incident hyperglycaemia. Our findings on a positive association between rice-based diet and hyperglycaemia are consistent with current knowledge. White rice, the predominant form of rice consumed among our study population, has a high glycaemic index (GI) and increases the risk of diabetes[37]. This may also have contributed to the rapid increase of diabetes in China over the past two decades[38].

Several cross-sectional and longitudinal studies have assessed the association between a rice-based dietary pattern and diabetes or hyperglycaemia with inconsistent results. In a regional study in Tianjin (north China)[39], a dietary pattern with high loadings of rice and red meat was not associated with impaired fasting glucose (IFG). However, another regional study in Nanjing (south China) found a healthy dietary pattern (vegetables, rice, fish and shrimp) was inversely associated with 3-year incident hyperglycaemia[40]. In the China Kadoorie Biobank (CKB) study, about half a million adults were followed for 7 years. Compared with a traditional northern pattern (high intake of wheat), a traditional southern pattern (high intake of rice) was associated with 70 % increased risk of incident diabetes (unpublished results). These conflicting findings may be partly due to the differences in the composition of the dietary pattern identified in different studies, especially the contrast between rice and wheat. For example, in the Tianjin study, wheat consumption across tertiles of rice-red meat pattern was high with a small absolute difference (147, 143, 136 g/d), whereas the rice intake was 71, 132, 199 g/d, respectively. Across tertiles of the rice-red meat pattern, the difference of the ratios between rice and wheat intake were smaller than those of the traditional pattern in our study. We have previously shown that the percentage of rice as the staple food was positively associated with the risk of incident hyperglycaemia[41].

The association between a traditional rice-based dietary pattern and hyperglycaemia is not mediated by obesity. Findings from CKB suggested that the rice-based southern dietary pattern was inversely association with obesity[42]. In our study, there was no significant difference in BMI across quartiles of the traditional lunch or dinner patterns at baseline. In the cohort, we found rice intake was inversely associated with weight gain but positively associated with incident hyperglycaemia over 5 years[41]. In sensitivity analyses, we found that rice consumption at dinner had a greater risk of IFG than consumption at lunch (data not shown). The finding is consistent with a previous study, which showed that high-GI carbohydrates at dinner produce greater postprandial glucose response compared with consuming a high-GI product in the morning[43]. This could be due to the high consumption of rice at lunch being compensated for by physical activity in the afternoon. However, this may not be the case for a high consumption at dinner.

Timing of energy intake during the day may be associated with the risk of obesity and other health outcomes[44]. In a 12-week weight loss experimental study, participants assigned to a high energetic breakfast group lost more weight than the high energetic dinner group. The high energetic breakfast group had a greater decrease of insulin resistance than the high energetic dinner group[45]. In line with current knowledge, we found a high energetic intake at breakfast was inversely associated the risk of incident hyperglycaemia. However, the association between meal-specific traditional breakfast pattern and incident hyperglycaemia was independent of the energy intake distribution of meals. It suggests that the energy intake during breakfast and also the composition of breakfast is important in relation to the risk of hyperglycaemia. Having an adequate energy intake at breakfast as well as choosing the right breakfast composition should be tested as a measure to prevent diabetes in China.

Although glycaemic load was positively associated with incident hyperglycaemia after adjusting for age, sex and energy intake, the association became non-significant after further adjustment for other covariates and dietary patterns. It could be hypothesised that the distribution of glycaemic load during the day varies by different dietary patterns. Dietary patterns may also cluster with other behaviours which may affect the risk of diabetes, for example daytime nap. Thus, dietary patterns may be more important than overall glycaemic load in relation to hyperglycaemia.

Fresh vegetables had high loadings for the traditional pattern at all three meals. However, it was only the traditional wheat breakfast that was inversely associated with hyperglycaemia, whereas the other two were positively associated with hyperglycaemia. This emphasises the importance of the combination of foods in a certain diet. The combination of rice and vegetable increases the risk of hyperglycaemia. For prevention of diabetes in China, the fact that vegetable intake seems not to be able to compensate for the association of rice with diabetes is potentially important. Findings from the study support the concept that all meals are important. However, findings of meal-specific dietary patterns could help in tailoring dietary advice to assist the population to achieve the recommended daily intakes of food and nutrients as well as meal preparation. In the Chinese food culture, it may be difficult for a high proportion of people to switch from rice to wheat as the staple food at lunch and dinner time. However, adopting a wheat-based breakfast is feasible and may help to prevent diabetes. Randomised clinical trials are needed to test the effectiveness and efficacy of this simple intervention.

Several limitations of this study exist and have been described in detail elsewhere[46], including the high rate of loss to follow-up. Due to the limited incident cases of diabetes, it was not informative to use diabetes as the main outcome. The amount of variance in the outcome explained by the identified dietary factors is small but similar to another study in China[47]. However, in our study, we used 3-d weighed food record giving detailed information on meal-based dietary intake rather than a FFQ. The strengths of the prospective study are that blood glucose levels were measured at both time points, and a detailed collection of baseline diet and lifestyle factors was undertaken. Although dietary misreporting is possible, it is considered unlikely to be differential with respect to future incident hyperglycaemia.

In conclusion, a rice-based traditional lunch and dinner is independently associated with an increased risk of hyperglycaemia in Chinese adults. A traditional wheat-based breakfast is associated with a decreased risk of hyperglycaemia.

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Z. S. contributed to the study design, conduct, data collection and statistical analysis and manuscript writing. M. R., A. T. and M. N. contributed to data analysis; Z. S., M. R., A. T. and M. N. contributed to manuscript revision. All authors read and approved the final manuscript.

The authors declare that there are no conflicts of interest.

Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S000711451700174X

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