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Relationship between dietary intake and the development of type 2 diabetes in a Chinese population: the Hong Kong Dietary Survey

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Abstract

Objective: To study the relationship between dietary intake and the development of type 2 diabetes among Chinese adults.

Design: A prospective cohort study. Dietary assessment was carried out using a validated FFQ. Principal component analysis was used to identify dietary patterns. Dietary glycaemic load and variety of snacks were also calculated.

Setting: A hospital-based centre at the Queen Mary Hospital in Hong Kong SAR, China.

Subjects: A total of 1010 Chinese adults aged 25–74 years who participated in a territory-wide dietary and cardiovascular risk factor prevalence survey in 1995–1996 were followed up for 9–14 years for the development of diabetes.

Results: A total of 690 (68·3 %) individuals completed follow-up during 2005–2008 and seventy-four cases of diabetes were identified over the follow-up period. Four dietary patterns were identified ('more snacks and drinks', 'more vegetables, fruits and fish', 'more meat and milk products' and 'more refined grains'). After adjustment for age, sex, BMI, waist-to-hip ratio, smoking, alcohol intake, participation in exercise/sports and family history of diabetes, the more vegetables, fruits and fish pattern was associated with a 14 % lower risk (OR per 1 SD increase in score = 0·76; 95 % CI 0·58, 0·99), whereas the more meat and milk products pattern was associated with a 39 % greater risk of diabetes (OR per 1 SD increase in score = 1·39; 95 % CI 1·04, 1·84). Dietary glycaemic load, rice intake, snack intake and variety of snacks were not independently associated with diabetes.

Conclusions: The more vegetables, fruits and fish pattern was associated with reduced risk and the more meat and milk products pattern was associated with an increased risk of diabetes.

Keywords
Chinese
Dietary patterns
Mediterranean diet
Type 2 diabetes

Dietary factors have been shown to contribute to the development of glucose intolerance. Foods with high dietary glycaemic index and load, low dietary fibre, carbohydrate-rich foods[1,2], excessive energy intake[3] and high fat intake (particularly saturated fats)[4] may predispose to glucose intolerance. On the other hand, high intakes of fish[5], potato, vegetables, legumes and vitamin C[6] are inversely associated with the development of type 2 diabetes. However, these individual nutrients or foods alone probably explain only a small part of the dietary effect on glucose metabolism.

Recently, dietary pattern analysis has emerged as an alternative and complementary approach to examining the relationship between diet and the risk of chronic diseases[7]. Several studies have examined dietary patterns and diabetes incidence[8–10]. However, these studies were conducted in Caucasians, who may differ significantly from Chinese in terms of lifestyle, diet and body physiology. The traditional Chinese diet, with a low fat content and plenty of vegetables[11], would be expected to reduce the likelihood of development of diabetes but only rarely has this been investigated prospectively in the Chinese population[12].

Studies have also highlighted the role of food variety in body fat accumulation[13,14]. A wide variety of sweets, snacks and carbohydrates, coupled with a low variety of vegetables, appears to promote long-term increases in

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energy intake and body fat[13]. In the Hong Kong Chinese population, increased variety of snack consumption was associated with increased risk of developing overweight[14]. Therefore, it would be of particular interest to examine snack intake and variety of snacks as predisposing factors to diabetes in this population.

In a 9–14-year follow-up of participants recruited into a territory-wide dietary and cardiovascular risk factor prevalence survey carried out in 1995–1996, in which detailed dietary information was also obtained from a subsample, we aimed to identify dietary patterns in a Chinese population and examine the relationship of dietary pattern and dietary intake, including dietary glycaemic load, rice intake, snack intake and variety of snacks, with the development of diabetes in this population.

Methods

Study population

The Hong Kong Dietary Survey was conducted at baseline from October 1995 to May 1996 as part of the territory-wide Cardiovascular Risk Factor Prevalence Survey in ethnic Chinese. A detailed description of the sample for the Cardiovascular Risk Factor Prevalence Survey has been published elsewhere[15]. In brief, participants were contacted by a random telephone survey and invited to a hospital-based centre at the Queen Mary Hospital, Hong Kong SAR, China, for physical examination and blood tests. Information on demographics, current smoking status, alcohol intake, participation in exercise/sports and family history of diabetes was also obtained using an interviewer-administered questionnaire. Current smokers were defined as those who reported having smoked at least one cigarette per day for at least 6 months before the interview. Drinkers were defined as those who drink at least once a month. Participants were also categorized as 'participated in exercise/sports' if they reported that they had been, or were currently, participating in exercise/sports 1 month before the interview. Family history of diabetes was defined as having at least one first-degree relative with diabetes.

Participants were divided by gender and age (five age groups: 25–34, 35–44, 45–54, 55–64 and 65–74 years). Thus, a total of ten groups were established. Dietary assessment was carried out consecutively on those who attended, until 100 or more participants were recruited into each of the ten sex- and age-specified groups. The response rate from the telephone survey was approximately 80 %; of those who responded, 40 % participated in blood tests and in recording anthropometric measurements. The sample closely matched the Hong Kong general population, since there was no difference in age distribution or socio-economic characteristics between subjects attending for blood tests and measurements, those who participated in the telephone survey, and the population as a whole as described in the 1996 Hong Kong by-census. There were also no significant differences in physical or laboratory parameters between subjects from the three geographical regions (Hong Kong Island, Kowloon and New Territories)[16].

The overall Cardiovascular Risk Factor Prevalence Survey included 2900 attendees aged 25–74 years, of whom 1010 (510 female and 500 male) underwent dietary assessment. The mean age of the dietary study participants was 45·6 (SD 11·7) years. From January 2005 to December 2008, the original cohort was invited to re-attend repeat blood tests and recording of anthropometric measurements, including weight, height and circumference measurements of waist and hip. A total of 690 of the 1010 participants returned (68·3 %). The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Ethics Committees of the Chinese University of Hong Kong and the University of Hong Kong. Written informed consent was obtained from all participants.

Dietary assessment

Dietary assessment was carried out at baseline during 1995–1996 using an FFQ, the validity of which has been examined elsewhere[17]. This consisted of 266 items in the following seven categories: bread/pasta/rice (sixteen items); vegetables (sixty-three items); fruit (twenty-six items); meat (thirty-nine items)/fish (thirty-one items)/egg (five items); beverages (thirty-seven items); dimsum/snacks (thirty-nine items); soups (ten items); and oil/salt/sauces. Wherever possible, participants were instructed to maintain a brief dietary record of the preceding 7 d before the visit, during which time a survey on a week's diet would be carried out. On the day of the interview, each participant was asked to complete the questionnaire with information pertaining to the food item, the size of each portion and the frequency of consumption on a daily and weekly basis. Portion size was explained to the participants using a catalogue of pictures of individual food portions.

Data were cross-checked by examining the dietary pattern (e.g. if meals were skipped) to determine whether it corresponded to the number of times staple foods such as rice or noodles were consumed over a 1-week period. In case of discrepancies, the questionnaire was re-checked with the participant. The amount of cooking oil was estimated according to the method of preparing different foods: 0·2 tablespoon for steaming fish or for stir-frying half a portion of vegetables and one tablespoon for stir-frying one portion of vegetables or one portion of meat. The type of oil used was also documented to allow an estimation of the quantity of fat used in cooking. Quantification of nutrients was carried out using food tables for Hong Kong compiled from *McCance & Widdowson's The Composition of Foods*[18] and two food tables used in China published by Zhongshan University[19] and the Institute of Health of the Chinese Medical Science Institute[20].

To identify dietary patterns, individual food items from the FFQ were first aggregated into groups. We formed

Table 1 Food group factor loading for four dietary patterns in the Hong Kong Adult Dietary Survey

	Dietary pattern			
	More snacks and drinks	More vegetables, fruits and fish	More meat and milk products	More refined grains
Chinese dimsum	0·897	–	–	−0·116
Tea	0·799	–	–	–
Soup	0·749	–	–	–
Cakes, cookies, pies and biscuits	0·405	–	–	–
Wine	0·317	–	–	–
Fast food	0·292	–	–	–
French fries and potato chips	0·259	–	–	–
Coffee	0·255	–	–	–
Sweets and desserts	0·220	–	–	–
Refined grains	0·169	–	0·374	0·898
Beverages	0·168	–	0·367	–
Poultry	0·154	–	0·348	–
Red meats	–	–	0·920	−0·198
Organ meat	–	–	0·273	–
Fish and seafood	–	0·715	0·163	0·172
Eggs	–	–	0·370	–
Nuts	–	0·222	–	–
Mushrooms and fungi	–	0·295	–	–
Cruciferous vegetables	–	0·269	–	–
Soya	–	0·278	–	–
Dark green and leafy vegetables	–	0·473	−0·115	–
Other vegetables	–	0·598	0·156	–
Fruit	–	0·659	−0·186	–
Fats and oils	–	–	–	–
Preserved vegetables	–	–	–	–
Tomatoes	–	0·202	–	–
Legumes	–	0·316	–	–
Condiments	–	–	0·376	–
Starchy vegetables	–	0·194	–	–
Whole grains	–	–	–	–
Milk	–	–	0·444	–
Eigenvalues	2·14	1·51	1·27	1·14
Variance explained (%)	17·95	12·69	10·65	9·51

Positive loadings <0·15 and negative loadings >−0·10 were omitted for simplicity.
The food groups are presented in descending order of loading values on the snacks and drinks dietary pattern.

thirty-one separate food groups on the basis of similarity of type of food and nutrient composition (Appendix). Some individual food items were preserved either because it was inappropriate to incorporate them into a certain food group (e.g. coffee, mayonnaise and tomatoes) or because they were suspected to represent distinct dietary patterns (e.g. preserved radish). Principal component analysis (PCA) was conducted with Varimax rotation to the thirty-one food groups. Factors with eigenvalues ≥1 were retained. Four factors with eigenvalues ≥1·14 and explaining 50·8 % of the variance were identified (Table 1). We labelled the first factor as more snacks and drinks, the second factor as more vegetables, fruit and fish, the third factor as more meat and milk products and the fourth factor as more refined grains. A factor score was then calculated for each participant for each of the four patterns, in which the standardized intakes of each of the thirty-one food groups were weighted by their factor loadings and summed.

The glycaemic index values for each food item in the FFQ were obtained from the international table of glycaemic index and glycaemic load values of foods[21], as well as from several publications on the glycaemic index of commercially available foods in the UK[22,23], from the China Food Composition Table[24] and also from a recent article about the glycaemic index in cereals and tubers produced in China[25]. The dietary glycaemic index for each participant was calculated by summing the products of the percentage contribution of each individual food to daily available carbohydrate intake multiplied by the food's glycaemic index value. Available carbohydrate was calculated as total carbohydrate minus dietary fibre[21]. The dietary glycaemic load was also calculated by multiplying the dietary glycaemic index by the total amount of daily available carbohydrate intake (divided by 100).

Variety of snacks was calculated on the basis of the percentage of different food items consumed within the snack food group, regardless of the frequency with which they were consumed, as well as their portion. In addition, the quality of diet was examined by applying the Dietary Quality index-International (DQI-I)[26], which has been used to evaluate the quality of the Mediterranean diet[27]. Essentially, four major aspects of the diet are assessed: variety, adequacy, moderation and overall balance, each with subcomponents. The range is 0–100, with a high score representing high quality. In the present study, we did not have sufficient information to calculate the category of empty-energy foods under the aspect 'moderation'. Therefore, the range of scores for moderation was 0–24 instead of 0–30, and the DQI-I total score was 0–94 instead of 0–100.

Outcome ascertainment

The WHO Study Group (1998) criteria for glucose intolerance and diabetes were used to classify participants into glucose tolerance groups. Diabetes was diagnosed if fasting glucose was ≥7·0 mmol/l and/or the 2 h post-glucose load was ≥11·1 mmol/l. Impaired glucose tolerance (IGT) was diagnosed if fasting glucose was <7·0 mmol/l and the 2 h post-glucose load was ≥7·8 mmol/l but <11·1 mmol/l. Impaired fasting glucose (IFG) was diagnosed if fasting glucose was ≥6·1 mmol/l but <7·0 mmol/l and the 2 h post-glucose load was <7·8 mmol/l.

Statistical analysis

The Student t test and the χ^2 test were used to test for differences in mean age, obesity indices and selected dietary factors, as well as for differences in distribution of the characteristics of participants who were alive and had completed interviews and those who were lost to follow-up. Multivariable Cox proportional hazards regression was used to calculate the OR and 95 % CI of incident diabetes by 1 SD increase in continuous dietary pattern scores of each PCA-derived dietary pattern. Age (in years, continuous), sex, BMI (in kg/m^2, continuous), waist-to-hip ratio (WHR; continuous), current smoking status (categorical), alcohol intake (categorical), participation in exercise/sports (categorical) and family history of diabetes (categorical) were considered as potential confounders. The above analyses were also performed for dietary glycaemic load (continuous), rice intake (in g/week, continuous), snack intake (in g/week, continuous), variety of snacks (in %, continuous) and DQI-I (continuous). Moreover, the Cox models above were repeated using the prevalence cases of IGT/IFG and diabetes at follow-up as the outcome. Prevalence cases of IGT/IFG and diabetes included those with IGT/IFG or diabetes at baseline and again at follow-up, in addition to the incident cases of IGT/IFG or diabetes (i.e. cases in the N-I, N-D, I-I, I-D and D-D groups). A value of $P < 0·05$ was used to denote significant difference. All analyses were performed using the Statistical Package for the Social Sciences statistical software package version 17·0 (SPSS Inc., Chicago, IL, USA).

Results

Of the 1010 participants included at baseline, 690 (68·3 %) completed interviews at a mean of 11·8 years of follow-up and 320 (31·7 %) were lost to follow-up. Those who were lost to follow-up were slightly older ($P < 0·01$), had higher WHR ($P < 0·01$) and had slightly higher dietary glycaemic load ($P = 0·096$) and rice intake ($P < 0·05$). Nevertheless, there were no differences in BMI, snack intake, variety of snacks and DQI-I between those who were lost to follow-up and those who returned (Table 2).

Table 2 Comparison between those alive at 10-year follow-up and those lost to follow-up, Hong Kong Dietary Survey

	Completed follow-up (*n* 690)		Lost to follow-up (*n* 320)		
	n	%	*n*	%	*P* value
Sex					
Male	330	47·8	170	53·1	0·117
Female	360	52·2	150	46·9	
Age (years)					
<35	162	23·5	76	23·8	<0·001
35–44	202	29·3	61	19·1	
45–54	191	27·7	60	18·8	
≥55	135	19·6	123	38·4	
No participation in exercise/sports	395	57·4	192	60·4	0·375
Have family history of DM	105	15·3	45	14·2	0·639
Current smoker	154	22·4	88	27·5	0·077
Drinker	123	18·0	71	22·3	0·108
	Mean	SD	Mean	SD	
Age (years)	44·4	10·75	48·2	13·06	<0·001
BMI (kg/m^2)	24·1	3·53	24·3	3·81	0·371
WHR	0·836	0·084	0·855	0·084	0·001
Dietary glycaemic load	158·2	58·74	164·9	59·36	0·096
Rice intake (g/week)	827·8	867·33	951·0	955·04	0·042
Snack intake (g/week)	236·2	385·05	287·6	498·62	0·103
Variety of snacks (%)	6·8	7·27	7·0	7·21	0·719
DQI-I (total)	61·3	9·99	60·7	9·97	0·434

DM, type 2 diabetes; WHR, waist-to-hip-ratio; DQI-I, Dietary Quality index-International.

Table 3 Ten-year changes in glucose tolerance categories, Hong Kong Dietary Survey

	Men (*n* 330)		Women (*n* 360)		Total (*n* 690)	
	n	%	*n*	%	*n*	%
Participants with normal fasting glucose at baseline (*n* 550)						
N-N	192	58·2	215	59·7	407	59·0
N-I	57	17·3	50	13·9	107	15·5
N-D	20	6·1	16	4·4	36	5·2
Participants with IGT/IFG at baseline (*n* 104)						
I-N	7	2·1	18	5·0	25	3·6
I-I	18	5·5	23	6·4	41	5·9
I-D	17	5·2	21	5·8	38	5·5
Participants with DM at baseline (*n* 36)						
D-D	19	5·8	17	4·7	36	5·2
Length of follow-up (years)	11·85	1·01	11·66*	1·09	11·75	1·06
Incidence of DM†		11·9		10·8		11·3

N-N, normal at baseline and follow-up; N-I, normal at baseline and IGT/IFG at follow-up; N-D, normal at baseline and DM at follow-up; IGT, impaired glucose tolerance; IFG, impaired fasting glucose; I-N, IGT/IFG at baseline and normal at follow-up; I-I, IGT/IFG at baseline and follow-up; I-D, IGT/IFG at baseline and DM at follow-up; DM, type 2 diabetes; D-D, DM at baseline and follow-up.
*$P \leq 0·05$ by *t* test comparing between sexes.
†Incidence of DM was calculated as N-D and I-D divided by the total number of participants without DM at baseline.

Of the 654 participants without diabetes at baseline, seventy-four (11·3 %) developed diabetes over the follow-up period (Table 3). Other categories of glucose tolerance changes are also shown (e.g normal to normal, IGT/IFG/diabetes remaining IGT/IFG/diabetes, IGT/IFG/diabetes becoming normal).

As shown in Table 4, a 1 SD increase in more vegetables, fruits and fish pattern score was associated with a 13 % lower diabetes risk (OR = 0·77; 95 % CI 0·59, 0·99) after adjustment for age, BMI, WHR, current smoking status, alcohol intake and participation in exercise/sports. Additional adjustment for family history of diabetes did not change the associations (OR = 0·76; 95 % CI 0·58, 0·99). In contrast, a 1 SD increase in more meat and milk products pattern score was associated with a 39 % increased risk of diabetes (OR = 1·39; 95 % CI 1·04, 1·84).

Table 5 shows the risk of developing diabetes for other dietary factors. There were suggestions of inverse associations of DQI-I and rice intake with the development of diabetes after adjustment for BMI, WHR, current smoking status, alcohol intake, participation in exercise/sports and family history of diabetes, but the relationships were not statistically significant (OR for DQI-I = 0·89, 95 % CI 0·69, 1·14; OR for rice intake = 0·87, 95 % CI 0·78, 1·34; Table 5). Further analyses on the relationships of diet with glucose intolerance and diabetes using prevalence cases of IGT/IFG and diabetes at follow-up as the outcome showed similar results (data not shown).

Discussion

In the present 9–14-year follow-up study of Hong Kong Chinese adults, we identified four dietary patterns using PCA, namely, more snacks and drinks, more vegetables, fruit and fish, more meat and milk products and more refined grains. The more vegetables, fruits and fish pattern, which was rich in vegetables, fruit, legumes and fish, was associated with a lower risk of diabetes. In contrast, the more meat and milk products pattern, which was rich in red meat, milk products and refined grains, was associated with a substantially higher risk of diabetes. These associations were independent of age, BMI, WHR, current smoking status, alcohol intake, participation in exercise/sports and family history of diabetes. However, no significant associations were observed between dietary glycaemic load, rice intake, snack intake, variety of snacks and the development of diabetes.

Several prospective studies have examined dietary patterns and diabetes incidence, but most of these studies were confined to Caucasians[8–10] and have rarely been carried out in the Chinese[12]. In general, two major patterns have been reported. A prudent or healthy diet, characterized by high consumption of vegetables, fruit, fish, poultry and whole grains, was associated with reduced risk of diabetes, whereas a Western diet, characterized by high consumption of red and processed meat, fried foods, high-fat dairy products, refined grains, sweets and desserts, was associated with increased risk. Our results are in agreement with these studies reporting that the more vegetables, fruits and fish pattern was associated with reduced risk of diabetes. The protective effects of fruit and vegetables on the development of diabetes could be attributed to their antioxidant properties, as well as to their dietary fibre and Mg content[28,29]. However, evidence regarding the role of fish intake in relation to diabetes risk has remained inconclusive[5,30]. It is possible that a high intake of fish may generally be an indicator of a more health-conscious attitude; therefore, a diet rich in fish may also be accompanied by a high consumption of vegetables and fruit, and thus reduced risk of diabetes.

The association between the more meat and milk products pattern and diabetes risk observed in the present study is also consistent with studies that showed an

Table 4 OR and 95 % CI of developing DM by an SD increase in continuous dietary pattern scores of each PCA-derived dietary pattern, Hong Kong Dietary Survey

	N-N (*n* 407)		N-D + I-D (*n* 74)		Model 1		Model 2		Model 3		Model 4	
Dietary patterns (servings/d)	Mean	SD	Mean	SD	OR*	95 % CI	OR*	95 % CI	OR*	95 % CI	OR*	95 % CI
More snacks and drinks	1·51	2·79	1·01	2·01	0·93	0·69, 1·25	0·90	0·67, 1·21	0·88	0·65, 1·19	0·86	0·67, 1·11
More vegetables, fruits and fish	6·51	3·22	6·11	3·07	0·83	0·64, 1·07	0·78	0·60, 1·02	0·77	0·59, 0·99	0·76	0·58, 0·99
More meat and milk products	4·11	2·59	4·05	2·21	1·19	0·92, 1·55	1·33	1·01, 1·75	1·38	1·04, 1·82	1·39	1·04, 1·84
More refined grains	2·05	1·23	2·05	1·16	1·04	0·82, 1·31	1·02	0·81, 1·29	1·03	0·82, 1·31	1·02	0·80, 1·29

DM, type 2 diabetes; PCA, principal component analysis; N-N, normal at baseline and follow-up; N-D, normal at baseline and DM at follow-up, I-D, IGT/IFG at baseline and DM at follow-up; IGT, impaired glucose tolerance; IFG, impaired fasting glucose.
*OR is per SD increase (using SD of the normal group as reference).
Model 1: adjusted for sex and age.
Model 2: adjusted for sex, age, BMI and waist-to-hip-ratio (WHR).
Model 3: adjusted for sex, age, BMI, WHR, current smoking status, alcohol intake and participation in exercise/sports.
Model 4: adjusted for sex, age, BMI, WHR, current smoking status, alcohol intake, participation in exercise/sports and family history of diabetes.

Table 5 OR and 95 % CI of developing DM by an SD increase in continuous dietary factor scores and dietary intake, Hong Kong Dietary Survey

	N-N (*n* 407)		N-D + I-D (*n* 74)		Model 1		Model 2		Model 3		Model 4	
Dietary variables	Mean	SD	Mean	SD	OR*	95 % CI	OR*	95 % CI	OR*	95 % CI	OR*	95 % CI
Dietary glycaemic load	158·6	59·89	159·5	48·64	1·05	0·82, 1·33	0·99	0·76, 1·28	1·02	0·78, 1·33	1·03	0·78, 1·34
Rice intake (g/week)	840·8	860·8	803·5	820·8	0·90	0·69, 1·18	0·88	0·68, 1·14	0·89	0·69, 1·15	0·87	0·67, 1·13
Snack intake (g/week)	238·0	372·5	244·1	395·7	1·07	0·89, 1·36	1·09	0·88, 1·35	1·10	0·89, 1·35	1·14	0·92, 1·41
Variety of snacks (%)	7·11	7·54	6·25	6·84	1·07	0·83, 1·40	1·15	0·90, 1·46	1·13	0·88, 1·43	1·18	0·92, 1·51
DQI-I (total)	61·0	10·02	60·7	9·88	0·87	0·69, 1·10	0·88	0·70, 1·12	0·88	0·69, 1·12	0·89	0·69, 1·14

DM, type 2 diabetes; N-N, normal at baseline and follow-up; N-D, normal at baseline and DM at follow-up; I-D, IGT/IFG at baseline and DM at follow-up; DQI-I, Dietary Quality index-International; IGT, impaired glucose tolerance; IFG, impaired fasting glucose.
*OR is per SD increase (using SD of the normal group as reference).
Model 1: adjusted for sex and age.
Model 2: adjusted for sex, age, BMI and waist-to-hip-ratio (WHR).
Model 3: adjusted for sex, age, BMI, WHR, current smoking status, alcohol intake and participation in exercise/sports.
Model 4: adjusted for sex, age, BMI, WHR, current smoking status, alcohol intake, participation in exercise/sports and family history of diabetes.

increased risk of diabetes for participants adhering to a Western diet[8–10]. The adverse effects of meat, milk products and refined grains have been attributed to their higher saturated fat and carbohydrate content, which may lead to hyperglycaemia and hyperinsulinaemia, and therefore higher risk of diabetes[1,31,32].

Although the dietary patterns observed in the present study were similar to the diets in Western populations, levels of whole grains consumption were rather low in our participants. Only about one-quarter of the study population consumed food containing whole grains, with the average intake being 0·11 (SD 0·59) servings/d. A diet high in whole grains has previously been associated with reduced risk of diabetes[8,33]. A recent study also showed that substitution of whole grains for white rice would produce a 36 % reduced risk of diabetes in both men and women[32]. Given the potential benefits of whole grains on glucose metabolism, further work would be needed to determine their role on diabetes prevention.

Studies have also highlighted the role of glycaemic load in the development of glucose intolerance and diabetes, but results have been inconsistent. Several prospective studies suggested positive associations of glycaemic index and glycaemic load with diabetes risk[1,34,35], whereas others did not show a positive association[36–38]. A lack of association between glycaemic load and measures of insulin sensitivity, insulin secretion and adiposity was also observed[39]. In our study, no associations were found between dietary glycaemic load and diabetes risk. Villegas *et al.*[1] suggested that divergent findings between studies could be due to differences in study methods. An FFQ that does not address carbohydrate quality in detail may provide inaccurate results. The FFQ used in the present study was validated and fairly detailed; however, higher dietary glycaemic load and rice intake were observed in those who were lost to follow-up, which may have introduced a bias into the estimation of the incidence of diabetes.

It has been pointed out that diets high in refined carbohydrates may lead to hypertension, dyslipidaemia and metabolic intermediaries of insulin resistance[40], and thus to diabetes risk. A recent study also found that a higher intake of white rice was associated with a 78 % increased risk of diabetes[32]. Previously, we reported a higher consumption of rice in participants with diabetes who had normal BMI[41]. However, in the present follow-up study, rice intake was not related to the risk of diabetes. It is possible that the diabetogenic potential of rice as a staple diet observed in some other studies is ameliorated by a higher consumption of vegetables, fruit and fish, components of the prudent diet. It is also possible that associations might be apparent with only a wide variation in the level of rice consumption in the study population in which rice is the major staple food.

Consumption of snacks and fast food has been associated with weight gain and obesity[13,14], the most important predisposing factor for diabetes. However, we have previously shown no difference in snack consumption among the glucose tolerance groups[41]. The findings from the present longitudinal study further support the suggestion that snack consumption was not a risk factor.

The limitations of our analysis should be noted. The number of new cases of diabetes was small; therefore, some predisposing factors may not have achieved statistical significance. Our measurement of diet was based on a single FFQ administered at baseline that may not have been representative of consumption over the long term. Furthermore, although the complete follow-up rate is 68 %, the possibility of selection bias from differential survival and other loss to follow-up is considerable.

In conclusion, our findings suggest that dietary patterns in the Hong Kong Chinese can predict risk of diabetes. However, no relationships of dietary glycaemic load, rice intake, snack intake and variety of snacks with the development of diabetes were observed. These findings add to the existing evidence that dietary patterns are important predictors for diabetes; however, further work is needed to determine their role in diabetes prevention, and thereby reduce the risk of diabetes in the Chinese population.

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Appendix

Food groupings used in the dietary pattern analysis of the Hong Kong Dietary Survey

Food groups	Food items
Beverages	Chocolate drinks, Horlicks, Ovaltine, Coca Cola, Sprite, fresh fruit juice, squash, chrysanthemum tea
Cakes, cookies, pies and biscuits	Apple pie, pork pie, cream crackers, semi-sweet biscuits, chocolate-coated biscuit, finger biscuit, walnut short cake, egg tart, spongy cake, madeira cake, malay pudding
Coffee	Coffee
Condiments	White sugar, honey, jam, syrup
Cruciferous vegetables	Broccoli, cabbage, celery cabbage, cauliflower
Dark green and leafy vegetables	Chinese flowering cabbage, white cabbage, kale, Chinese spinach, watercress, spinach, pea shoot
Dimsum	Wonton, barbecue pork bun, egg yolk and lotus seed bun, steamed dimsum, deep-fried dimsum, steamed rice roll, Chinese turnip pudding, deep-fried wheat strip, sticky rice dumpling
Eggs	Boiled egg, fried egg, limed duck egg, salted duck egg, quail egg, egg white, egg yolk
Fast food	Pizza, hamburger (McDonald's), filet-O-fish (McDonald's), chicken McNuggets (McDonald's)
Fats and oils	Mayonnaise
Fish and seafood	Grass fish, big head fish, mud carp dace fish, eel, Japanese eel, blace, golden thread fish, snakehead fish, carp, cat fish, garouper, mackerel, ribbon fish, big eye fish, squid, oyster, dried oyster, prawns, crab, scallops, sea cucumber, fish ball, fish cake, ink fish, mud carp ball, sardines, fried dace, tuna fish, salted fish, jelly fish, salmon, squid thread
French fries and potato chips	Hash brown potatoes, potato chips, potato crisps
Fruits	Orange, grapefruit, apple, pear, banana, strawberry, honeydew melon, watermelon, peach, prune, mango, apricot, grapes, papaya, lychee, logan, pineapple, cocktail fruit, lemon, pomelo, cherry, persimmon, kiwifruit, dried apricot, dried raisins, dried date
Legumes	Sprouted mung beans, soyabean sprout, red beans, brow beans, snap beans, snow peas, peas, broad beans, string beans, mungbean thread
Milk and milk products	Cow's milk, skimmed milk, chocolate milk, dried whole milk, dried skimmed milk, sweetened condensed milk, evaporated milk, cheese, yoghurt, low-fat yoghurt, ice cream, milk shake, milk pudding
Mushroom and fungi	Fresh mushrooms, dried mushrooms, canned mushrooms, white fungus, wood fungus, black moss
Nuts	Chestnut, cashew nut, peanut, peanut butter
Organ meats	Ox belly, ox tongue, chicken liver, chicken heart, pig liver, pig heart, pig kidney, beef oval, liver sausage
Other vegetables	Lettuce, Chinese chives, water spinach, asparagus, celery, onion, carrots, radish, water chestnut, lotus root, bamboo shoot, hairy melon, bitter cucumber, winter melon, red pepper, green pepper, sweet corn, canned sweet corn, angled loofah, egg plant
Poultry	Chicken with or without skin, chicken meat, chicken mid-wing, chicken wing quarter, chicken leg quarter, roast goose with or without skin, roast duck with or without skin, roast pigeon, chicken paw
Preserved vegetables	Preserved radish
Red and processed meat	Lean and fat pork, lean and fat sparerib, lean roasted pork, 24 % fat roast port, pork chop, fried beef, fried steak, lamb, fried sausage, big red sausage, Chinese sausage, preserved duck, preserved pork, ham, luncheon meat, hamburger, salami, dry beef, pork stick, beef floss, pork floss
Refined grains	Cooked rice, soft rice, congee, wheat noodles, instant noodles, flattened rice noodles, macaroni, spaghetti, mann-tau, plain roll, bread, sweet roll
Soups	Cream of chicken soup, Chinese soup with lotus seed, soup with green and red carrots, soup with watercress, soup with kudzu and carp, soup with cauliflower and potato, soup with peanut and chicken paws, soup with brow beans and peanuts, soup with hairy cucumbers and dried squid, soup with green vegetables and bean curd
Soya	Fresh soyabean, bean curd, bean curd sheet, fried bean curd, bean curd square, bean curd stick, vegetarian chicken, soyabean in tomato sauce, vitasoy, soya drink
Starchy vegetables	Sweet potato, potato, pumpkin
Sweets and desserts	Red bean sweet soup, chocolates, candy
Tea	Chinese tea, green tea, ginseng tea, tea (Lipton)
Tomatoes	Tomatoes
Whole grains	Porridge, cornflakes, frosties, whole-wheat bread, wheat gluten
Wine	Wine, spirit, beer