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The association between dietary patterns with type 2 diabetes mellitus and pre-diabetes in the Henan rural cohort study

Yuan Xue[1], Chang Liu[2], Bingya Wang[1], Zhenxing Mao[3], Songcheng Yu[1], Yan Wang[1], Dongdong Zhang[1], Chongjian Wang[3], Wenjie Li[1,*] and Xing Li[1,*]

[1]Department of Nutrition and Food Hygiene, College of Public Health, Zhengzhou University, Zhengzhou, Henan 450001, China: [2]Department of Clinincal Nutrition, The Fifth Affiliated Hospital of Zhengzhou University, Zhengzhou, Henan, China: [3]Department of Epidemiology and Biostatistics, College of Public Health, Zhengzhou University, Zhengzhou, Henan, China

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Abstract

Objective: We aimed to investigate whether dietary patterns were associated with the risk of type 2 diabetes mellitus (T2DM) or pre-diabetes in adults of rural area in Henan.

Design: Cross-sectional study. Principal component analysis was used to identify dietary patterns, while multivariate logistic regression analysis and restricted cubic spline regression models were used to analyse the association between dietary patterns and both pre-diabetes and T2DM.

Setting: Rural area of Henan province, China.

Participants: A total of 38 779 adults aged 18–79 years were recruited from the Henan rural cohort study as the subjects.

Results: The prevalence of pre-diabetes and T2DM in rural Henan was 6·8 % and 9·4 %, respectively. A total of three dietary patterns were assessed in the present study. Dietary pattern I with a high intake of red meat and white meat; dietary pattern II with a high intake of grains, nuts, milk and eggs and dietary pattern III with a high intake of vegetables, staple food and fruits. The highest quintile (Q5) of pattern III could reduce 32·7 % risk of pre-diabetes. The Q5 of pattern II showed a 15·5 % decreased risk of T2DM, in a U-shaped dose–response manner; meanwhile, the Q5 of pattern III was significantly associated with reduced risks of T2DM (OR: 0·582, 95 % CI (0·497, 0·682)).

Conclusions: Pattern III is beneficial for reducing risk of pre-diabetes or T2DM. Though a higher consumption of 'grains-nuts-egg' may associate with a reduced risk of T2DM, excessive intakes should be avoided. This study may provide a reference for the prevention of diabetes on dietary precautions.

Keywords
Dietary patterns
T2DM
Pre-diabetes
Rural adults

Over recent decades, the worldwide prevalence of diabetes and impaired glucose tolerance in adults has increased drastically, especially in developing countries[1–4]. It has been estimated that 693 million or more people might suffer from diabetes worldwide by 2045, while 374 million people would become impaired glucose tolerance patients[5]. The prevalence of diabetes in China has more than quadrupled in past decades; an estimated 110 million adults have suffered from diabetes in 2010, and 490 million adults were diagnosed as pre-diabetes[6]. Moreover, the prevalence of diabetes in Chinese rural areas was 4·1 %[7], sugesting that diabetes issues in rural China cannot be ignored.

Genetic variations play an important role in the development of the disease, while epidemic data indicate that lifestyle changes, as well as environmental exposures, contribute to an increased risk of type 2 diabetes mellitus (T2DM)[8]. It is well known that diet is one of the main affecting factors of a variety of diseases[9]. Recent studies have shown that with the onset of diabetes, food choice and eating habits played a crucial role in controlling disease progression[10].

There are many studies that assessed the relationship of dietary patterns and diabetes in China; however, there is a gap and controversies in this area[11–14]. The research of Cai *et al.* showed that the 'meats' and 'grains' dietary patterns

*Corresponding authors: Email lwj@zzu.edu.cn; lixing530@zzu.edu.cn

were associated with an increased risk of T2DM, whereas the 'dairy product' dietary pattern showed no association with the risk of T2DM[11]. The study of Shu *et al.* indicated that western dietary pattern was associated with an elevated risk, whereas the grains–vegetables dietary pattern was associated with a reduced risk of T2DM[13].

In traditional epidemiology, the main approach is to establish the relationship between nutrients or food with chronic diseases, such the case of diabetes. However, human diet is a complicated issue, as food consumed in China is varied and there are synergistic or inhibitory effects among nutrients, making it difficult to verify these possible associations. Nevertheless, the use of dietary patterns may overcome these limitations via analysing the effects of multiple dietary factors on the individual's health[9,15]. Many diabetes-related studies have found that early lifestyle modifications, particularly healthy diets and exercises, were effective in delaying the onset of diabetes[16].

Thus, it is important to know the eating patterns of diabetic individuals and their association with clinical aspects of the disease. In rural China, no studies have yet analysed the dietary patterns in both T2DM and pre-diabetes, nor their relationship with glycaemic control. In this study, we aimed to identify the main dietary patterns of patients with T2DM or pre-diabetes.

Methods

Study population

Data from the baseline survey of the Henan Rural Cohort were used to analyse the association between dietary patterns and T2DM. The Henan Rural Cohort was an ongoing cohort including 39 259 individuals aged 18–79 years in five rural regions of Henan province in China (Suiping county, Yuzhou county, Xinxiang county, Tongxu county and Yima county) at baseline (2015–2017). The cohort detail information is described elsewhere[17]. For the present analysis, we excluded participants with type 1 diabetes (*n* 4), gestational diabetes (*n* 64), malignant tumours (*n* 332) and kidney failure (*n* 18). We additionally excluded participants with missing information on fasting glucose (*n* 63). This resulted in a final sample size of 38 779 participants for analyses. And, all participants completed the informed consent.

Data collection

Data were collected from a standard questionnaire including information on general demographic characteristics, lifestyles, personal and family history of diseases that was completed by well-trained investigators by face-to-face interview. Venous blood samples were collected for routine blood measurements, biochemical indexes after at least 8 h of overnight fasting. Fasting plasma glucose (FPG), TAG, total cholesterol and HDL-cholesterol were assayed by an automatic chemistry analyzer (Cobas C501, Roche Diagnostics GmbH). Glycosylated HbA1C was determined enzymatically on an automatic analyser. Insulin was measured using RIA. Anthropometric measurements included height, weight, waist circumference, resting blood pressure, heart rate and lung function. Subjects were in light clothing and without shoes when measuring anthropometric variables. Two measurements of height and weight were performed to the nearest 0·1 cm and 0·1 kg separately, on the basis of a standard protocol. Blood pressure measurements were performed after 5-min rest in seated position, with 30-s intervals between measurements, using an electronic sphygmomanometer (HEM-770AFuzzy). The average of the three measurements from the right arm of every person was applied to the analyses. All the measurements and tests were collected using standard protocol by trained staff. The detailed data collection protocol has been described elsewhere[18,19]. BMI was calculated as weight divided by the square of height.

Dietary assessment

Dietary data were collected via a self-reported FFQ, which was evaluated for reliability and validity[20]. A food consumption questionnaire contains eleven-item food groups including staple food such as rice, noodles and steamed bread; red meat such as pork, lamb and beef; white meat such as chicken and duck; fish including freshwater and marine fish; eggs such as chicken, duck and goose eggs; milk and dairy products including milk, goat's milk, yogurt, cheese and other dairy products; fruits; vegetables; legumes and products like soya beans, mung beans, red beans, black beans, broad beans, tofu, soya milk, dried tofu, vegetarian chicken, etc.; nuts and peanuts; grains like corn, sweet potatoes and sorghum. Consumption questions covering intake of food groups during the previous 12 months were asked by a trained investigator. Each item had a choice of five frequency categories (never, daily, weekly, monthly, yearly) and the amount (g/ml) of food consumed at that frequency. For each question, the respondents were shown a card with samples of a standard portion of each food group relevant for typical diets.

Definition of type 2 diabetes mellitus and pre-diabetes

The definition of T2DM and pre-diabetes was based on the American Diabetes Association diagnostic criteria (2018)[21]. After excluding type 1 diabetes, gestational diabetes and other special type of diabetes at the same time, pre-diabetes was defined as 5·6 mmol/l $\leqslant$ FPG < 7·0 mmol/l, or 5·7 % < HbA1C < 6·5 %. T2DM was confirmed as FPG $\geqslant$ p;7·0 mmol/l, or HbA1C > 6·5 %, or having a self-reported previous diagnosis of diabetes by a physician, or taking anti-glycaemic agents during the previous 2 weeks.

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Data analysis

Age was used on a continuous scale. Education was grouped into five categories (Illiteracy, Primary school, Middle school, High school, College and above) by asking the question 'What is your highest level of education?' Marital status was categorised as married, widowed, divorced and single. Smoking and drinking status were allocated to three categories as 'never, ever, current'. Per capita monthly income was calculated by total household income and family size and categorised into five groups and expressed in Ren Min Bi (RMB: <500 RMB, 500–999 RMB, 1000–1999 RMB, 2000–2999 RMB, ≥3000 RMB. Physical activity level was estimated based on self-reported activities and grouped into three categories (low, medium and high).

Dietary patterns were identified by factor analysis using the standard principal component analysis method. The varimax method was used for rotation in the analysis. Patterns were determined by scree plot, eigenvalue (>1) and factor interpretability by each factor. Labelling of the patterns was primarily descriptive and based on our interpretation of the pattern structures. Factor loadings are equivalent to simple correlations between the food items and the patterns. Factor loadings were presented in tabular form. Participants were assigned pattern-specific factor scores, which were calculated as the sum of the products of the factor loading coefficients and standardised daily intake of each food group is associated with that pattern.

Continuous data are presented as mean and SD or median and quartile (median (p25, p75)). Categorical data are presented as number and percentage. The categorical data of each group were compared by χ^2 test. The Kruskal–Wallis method was used to assess the differences in non-normally continuous data. Normally continuous data using one-way ANOVA assessed the P value. The circus diagram and Spearman's rank correlation coefficient were used to show the relationship between dietary patterns and variables. The association between diabetes/pre-diabetes and dietary patterns scores by using Multinomial logistic regression analysis and was adjusted for age, region, gender, education level, marital status and per capita monthly income in 'Model 1'. Health behaviours (BMI, smoking, alcohol drinking, physical activity and family history of diabetes) were further adjusted in 'Model 2'. 'Model 3' was the final adjusted model by additional energy. For the quintiles of each dietary pattern, the first quintile (Q1) was considered as the reference group. Restricted cubic spline[22] was used to explore the dose–response relationship between continuous factor scores with T2DM and pre-diabetes, with five knots located at 17th, 33rd, 50th, 67th and 83rd percentiles of factor scores. All the analyses were conducted using SPSS21.0 (IBM Corp.) and R software (version 3.5.3). Statistical significance was considered when $P < 0{\cdot}05$ with two-sided tested.

Results

Characteristics of study participants

A total of 38 779 remaining participants (15 368 males and 23 411 females) were included in the final analysis, and the mean age was 55·58 years. Table 1 presents the general characteristics of the participants according to case and control groups. The prevalence of pre-diabetes and T2DM was 6·8 % and 9·4 %, respectively. Statistically significant differences in gender, age, education level, marital status, region, per capita monthly income, physical activity, family history of diabetes, smoking and alcohol drinking were observed among different groups ($P < 0{\cdot}05$). Furthermore, height, weight, BMI, waist circumference, as well as expressions of total cholesterol, TAG, insulin, fasting glucose and HDL-cholesterol also differed significantly among different groups (Table 2). Table 3 displays the differences in food consumptions among three groups. According to our study, participants with T2DM were more likely to consume less red meat, white meat, eggs and fruits. Furthermore, participants with pre-diabetes tended to consume fewer staples, red meat, fish, milk, vegetables and nuts in daily life.

Definition of dietary patterns

The three-cluster dietary patterns were obtained according to scree plot, eigenvalue (Fig. 1, see online Supplemental Fig. S1) and factor interpretability (see online Supplemental Table S1), with an accumulating contribution rate of 43·56 %. Factor 1, the 'meat' pattern, characterised by a high intake of red and white meat. Factor 2, the 'grains-nuts-egg' dietary pattern, stands for a high intake of grains, nuts, milk and eggs. Factor 3, the 'vegetables-staple-fruits' pattern, is featured by a high consumption of vegetables, staple food and fruits.

Figure 1 exhibits the proportion of dietary patterns components' number of each group. The normal subjects conformed to 'meat' pattern, 'grains-nuts-egg' pattern and 'vegetables-staple-fruits' pattern were 31·6 %, 32·1 % and 36·5 %, respectively. Among people with pre-diabetes, the proportions of each pattern were 28·1 %, 40·0 % and 31·9 %. 30·9 % of T2DM patients were subjected to 'meat' pattern, 36·3 % with 'grains-nuts-egg' dietary pattern and 32·8 % with 'vegetables-staple-fruits' pattern.

Figure 2 and Table S2 show the relationship among dietary patterns with insulin, fasting glucose and food groups. The width of the ribbon represents the intensity of the correlation (in positive correlation). The top three correlation coefficients for the 'vegetables-staple-fruits' pattern were vegetables, staple and fruits. Egg, milk, bean and nut were closely related to the 'grains-nuts-egg' dietary pattern. For 'meat' pattern, red meat, white meat and fish were on the top of the menu. Furthermore, patients with 'vegetables-staple-fruits' pattern showed lower levels of fasting glucose and insulin, this pattern was negatively correlated with FPG ($r = -0{\cdot}106$, $P < 0{\cdot}001$) and positively correlated

Table 1 Subject characteristics according to the grouping

	Control		Pre-diabetes		T2DM			
	n	%	*n*	%	*n*	%	χ^2/F	*P**
Total†	32 491	83·8	2634	6·8	3654	9·4		
Gender							8·356	0·015
Men	12 869	39·6	1102	41·8	1397	38·2		
Women	19 622	60·4	1532	58·2	2257	61·8		
Age (years)							446·726	<0·001
Mean	54·78		58·66		60·39			
SD	12·45		10·53		9·24			
Education level							303·020	<0·001
Illiteracy	5067	15·6	530	20·1	857	23·5		
Primary school	8964	27·6	770	29·2	1163	31·8		
Middle school	13 297	40·9	944	35·8	1205	33·0		
High school	4112	12·7	354	13·4	373	10·2		
College and above	1051	3·2	36	1·4	56	1·5		
Marry							89·879	<0·001
Married	29 245	90·0	2322	88·2	3236	88·8		
Widowed	2501	7·7	282	10·7	378	10·3		
Divorced	185	0·6	8	0·3	16	0·4		
Single	560	1·7	22	0·8	24	0·7		
Region							669·134	<0·001
Yuzhou	7476	23·0	646	24·5	1056	28·9		
Zhumadian	14 119	43·5	696	24·5	1028	28·1		
Kaifeng	2017	6·2	72	6·5	285	7·8		
Xinxiang	8095	24·9	1066	40·5	1186	32·5		
Yima	784	2·4	54	2·1	99	2·7		
Income							46·827	<0·001
≤500 RMB	11 366	35·0	1007	38·2	1437	39·3		
~1000 RMB	10 739	33·1	859	32·6	1177	32·2		
~2000 RMB	7893	24·3	600	22·8	815	22·3		
~3000 RMB	1632	5·0	108	4·1	157	4·3		
≥3000 RMB	861	2·6	60	2·3	68	1·9		
Smoking							93·120	<0·001
Never	23 558	72·5	1879	71·3	2751	75·3		
Ever	2491	7·7	277	10·5	365	10·0		
Current	6442	19·8	478	18·1	538	14·7		
Drinking							56·875	<0·001
Never	25 098	77·2	1969	74·8	2882	78·9		
Ever	1429	4·4	137	5·2	228	6·2		
Current	5964	18·4	528	20·0	544	14·9		
Physical activity							131·488	<0·001
Low	10 134	31·2	970	36·8	1435	39·3		
Moderate	12 425	38·2	901	34·2	1295	35·4		
High	9932	30·6	763	29·0	924	25·3		
Family history of diabetes							350·549	<0·001
No	31 362	96·5	2512	95·4	3289	90·0		
Yes	1129	3·5	122	4·6	365	10·0		

T2DM, type 2 diabetes mellitus; RMB, Ren Min Bi.
*Continuous data are presented as mean and SD using one-way ANOVA assessed the *P* value.
†Categorical data are presented as numbers and percentages, and using χ^2 test.

Table 2 Levels of physical examination and biochemical traits of the participants in each group

	Control		Pre-diabetes		T2DM			
Variables	Median	p25, p75	Median	p25, p75	Median	p25, p75	χ^2	*P**
Height (cm)	159·20	154·00, 165·20	159·20	153·50, 165·50	158·10	153·00, 164·60	31·605	<0·001
Weight (kg)	62·10	55·30, 69·70	65·50	58·80, 73·70	65·40	58·20, 73·40	513·135	<0·001
BMI (kg/m^2)	24·44	22·18, 26·82	25·88	23·67, 28·26	25·99	23·76, 28·42	944·287	<0·001
WC (cm)	83·00	76·00, 90·00	88·10	81·45, 95·00	89·00	83·00, 96·00	1507·573	<0·001
TC (mmol/l)	4·60	4·03, 5·25	5·00	4·35, 5·70	4·91	4·28, 5·70	639·517	<0·001
TAG (mmol/l)	1·34	0·96, 1·91	1·54	1·11, 2·32	1·73	1·20, 2·57	782·463	<0·001
Insulin (mg/ml)	10·09	7·00, 13·12	10·90	7·40, 15·05	11·22	7·60, 15·39	260·263	<0·001
Fasting glucose (mmol/l)	5·10	4·77, 5·41	6·38	6·20, 6·60	8·04	7·19, 9·99	14 857·051	<0·001
HDL-cholesterol (mmol/l)	1·31	1·10, 1·54	1·24	1·05, 1·46	1·19	1·00, 1·43	440·117	<0·001

WC, waist circumference; TC, total cholesterol.
**P value* was assessed using the Kruskal–Wallis method.

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Table 3 Food consumption in each group

	Control		Pre-diabetes		T2DM			
Food groups	Median	p25, p75	Median	p25, p75	Median	p25, p75	χ^2	*P**
Staple food (g/d)	400·00	300·00, 500·00	400·00	300·00, 500·00	400·00	300·00, 500·00	46·580	<0·001
Red meat (g/d)	16·67	6·67, 42·86	14·29	6·67, 35·71	14·29	5·00, 35·71	49·893	<0·001
White meat (g/d)	6·67	1·67, 16·67	5·00	0·82, 14·29	5·00	0·82, 14·29	117·760	<0·001
Fish (g/d)	1·37	0·00, 5·00	0·82	0·00, 3·33	0·96	0·00, 4·11	54·722	<0·001
Egg (g/d)	62·50	17·86, 62·50	62·50	17·86, 62·50	62·50	17·86, 62·50	19·551	0·004
Milk (ml/d)	0·00	0·00, 16·67	0·00	0·00, 7·33	0·00	0·00, 17·56	21·038	<0·001
Fruits (g/d)	100·00	33·33, 200·00	85·71	28·57, 200·00	57·14	13·33, 200·00	441·666	<0·001
Vegetable (g/d)	250·00	200·00, 500·00	250·00	150·00, 400·00	250·00	200·00, 450·00	69·205	<0·001
Bean (g/d)	16·67	5·00, 42·86	16·67	6·67, 42·86	16·67	6·67, 42·86	8·224	0·016
Nuts (g/d)	6·85	0·41, 21·43	6·85	0·00, 21·43	6·67	0·00, 16·67	13·979	0·001
Grains (g/d)	35·71	13·33, 83·33	50·00	14·29, 100·00	35·00	8·33, 100·00	35·633	<0·001

**P value* was assessed using the Kruskal–Wallis method.

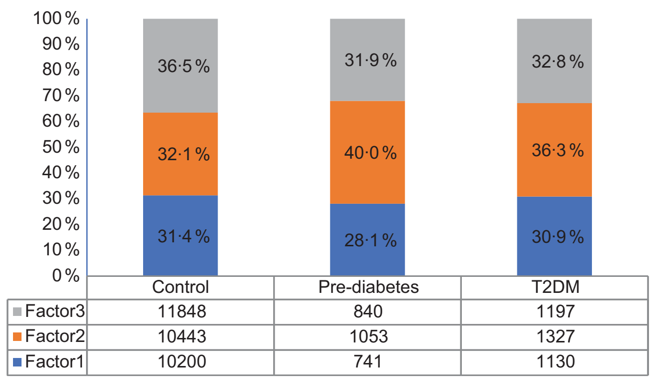

Fig. 1 The proportion of dietary patterns components' number of each group. Factor 1, 'meat' pattern; factor 2, 'grains-nuts-egg' dietary pattern; factor 3, 'vegetables-staple-fruits' pattern. T2DM, type 2 diabetes mellitus

with insulin ($r = 0·174$, $P < 0·001$), while 'meat' pattern was also negatively related to the fasting glucose level.

Table S3 presents the food consumption of each group based on the quintiles of different pattern factor scores. Under certain dietary patterns, the consumption of characteristic foods grows as the factor score increases. Take 'meat' pattern for example, the intake of fish, red and white meat advanced as the scores grew.

Relationship between dietary patterns and pre-diabetes

Table 4 and Fig. 3 show the associations between dietary patterns and pre-diabetes. In the crude model, the highest quintile (Q5) of the meat pattern was significantly associated with a reduced risk of pre-diabetes (OR: 0·678, 95 % CI (0·596, 0·771), $P_{trend} < 0·001$) as compared with the lowest quintile (Q1). After adjusting for covariates (models 1–3), the 'meat' pattern was not significantly correlated with pre-diabetes. There was no significant correlation between 'grains-nuts-egg' dietary pattern and pre-diabetes in both crude and adjusted models. In all models, the highest quintiles of 'vegetables-staple-fruits' pattern were significantly associated with reduced risks of pre-diabetes (OR crude: 0·616, 95 % CI (0·540, 0·703), $P_{trend} < 0·001$); (OR model 1: 0·690, 95 % CI (0·602, 0·791), $P_{trend} < 0·001$); (OR model: 2 0·708, 95 % CI (0·616, 0·813), $P_{trend} < 0·001$); (OR model 3: 0·683, 95 % CI (0·569, 0·820), $P_{trend} < 0·001$, respectively). There was a linear relationship for 'vegetables-staple-fruits' pattern in pre-diabetes according to the restrictive cubic spline.

The relationship between dietary patterns and type 2 diabetes mellitus

The OR of T2DM across quintiles of dietary patterns are shown in Table 4. Before adjustment (crude model), the highest quintile (Q5) of the 'meat' pattern was significantly associated with a reduced risk of T2DM (OR: 0·720, 95 % CI (0·645, 0·804), $P_{trend} < 0·001$) when compared with the lowest quintile (Q1). After adjusting for covariates (models 1–3), the 'meat' pattern was not significantly correlated with T2DM. Nevertheless, the restrictive cubic spline suggested a risk trend between 'meat' pattern and T2DM after fully adjusted.

The highest quintile of the 'grains-nuts-egg' dietary pattern was not significantly associated with a decreased risk of T2DM (OR: 0·942, 95 % CI (0·846, 1·049), $P_{trend} = 0·343$); however, there was a significant association in the fully adjusted model (OR: 0·845, 95 % CI (0·747, 0·956), $P_{trend} = 0·125$), and this dose–response relationship was shown to be U-shaped by restrictive cubic spline (Fig. 3).

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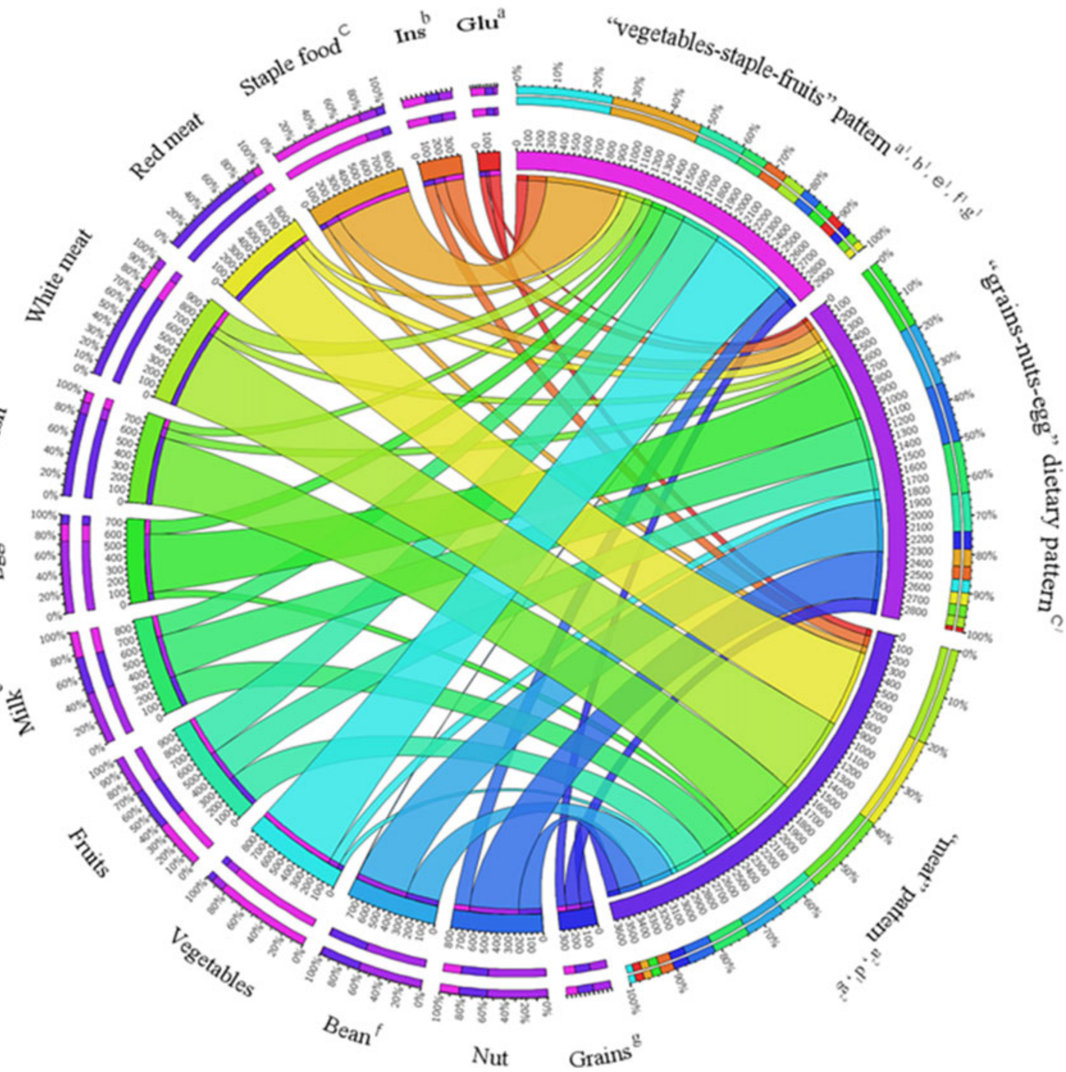

Fig. 2 The circus diagram of relationship between dietary patterns and variables. The correlation coefficient is negative between a and a1, a2, b and b1, c and c1, d and d1, e and e1, f and f1, g and g1, g2. The correlation coefficient was calculated by Spearman's rank correlation. Ins, Insulin. Glu, fasting glucose

The risk of T2DM decreased gradually as the intake of 'vegetables-staple-fruits' pattern increased. In both unadjusted and adjusted models, the highest quintiles of 'vegetables-staple-fruits' pattern were significantly associated with reduced risks of T2DM (OR unadjusted: 0·634, 95 % CI (0·567, 0·708), $P_{\text{trend}} < 0{\cdot}001$); (OR adjusted: 0·582, 95 % CI (0·497, 0·682), $P_{\text{trend}} < 0{\cdot}001$, respectively). A linear relationship between 'vegetables-staple-fruits' pattern and T2DM was shown by restrictive cubic spline (Fig. 3).

Discussion

Our study suggested that 'vegetables-staple-fruits' pattern is beneficial for reducing risk of pre-diabetes or T2DM, which is consistent with the results of previous studies[23–26]. Plant-based dietary patterns, which are rich in fruits, vegetables and whole grains, play a pivotal role in preventing various chronic diseases. A research reported that non-vegetarians were 74 % more likely to develop diabetes than vegetarians over 17 years of follow-up (via a 17-year period-study)[27]. Plant-based diet may help prevent and treat diabetes, possibly by improving insulin sensitivity and ameliorating insulin resistance[28]. Reports show that fruits, vegetables and whole grains may improve glycaemic control and reduce carbohydrate production and the risk of diabetes due to their low energy density, low glycaemic load, high fibre and antioxidant content[25,29]. Similarly, vegetarian and vegan diets have also been shown to improve plasma lipid concentrations and reverse atherosclerosis progression[24]. What is more? Vegetarian diet seems to be more effective in controlling glycaemia and plasma lipid concentrations[30]. In fact, the dietary pattern of high fruits and vegetables is indeed beneficial for the prevention of T2DM[31].

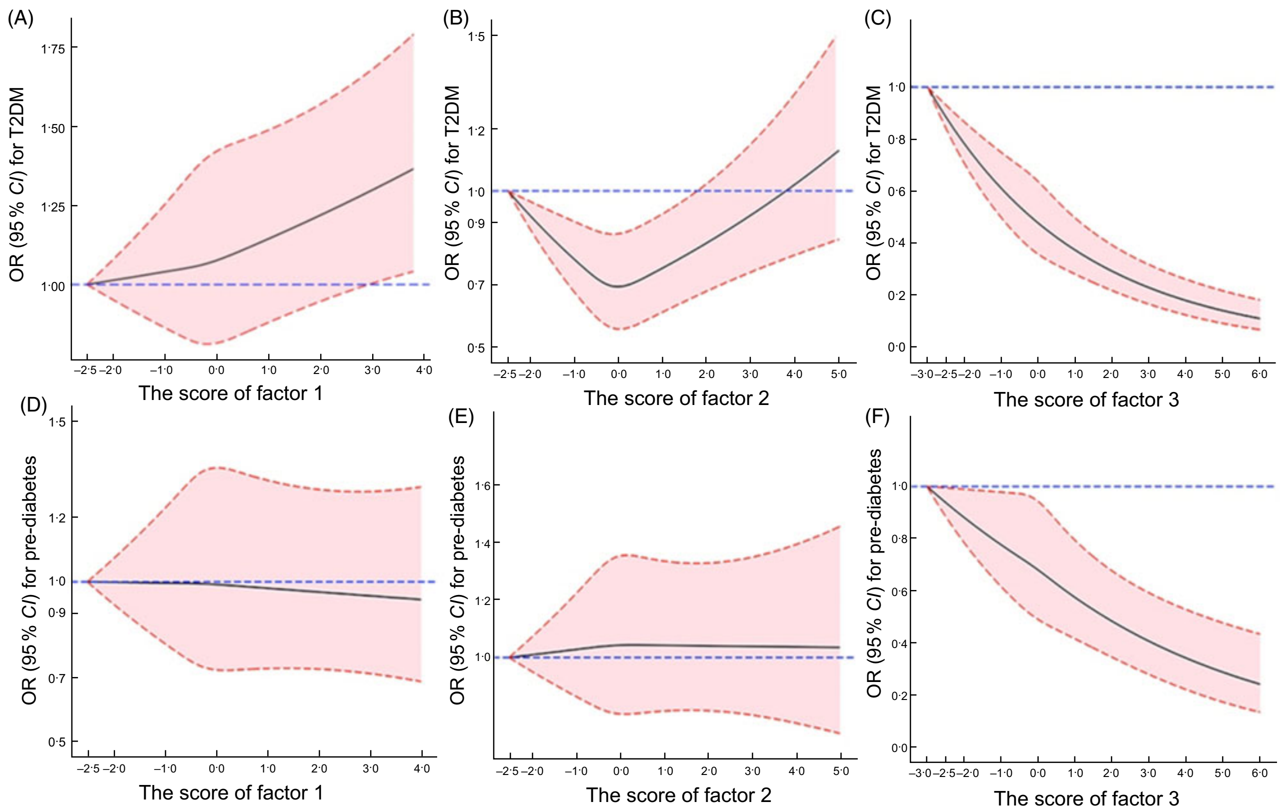

Fig. 3 Dose–response relationships between continuous factor score with T2DM and pre-diabetes. Fully adjusted model was adjusted for age, region, gender, education level, marital status, per capita monthly income, BMI, smoking, alcohol drinking, physical activity, family history of diabetes and energy. Factor 1, 'meat' pattern; factor 2, 'grains-nuts-egg' dietary pattern; factor 3, 'vegetables-staple-fruits' pattern

On the contrary, evidences have linked red meat intake to an increased risk of CAD, cancer and T2DM[32]. which is in consistent with our results. After adjusting for covariates, the 'meat' pattern was not significantly correlated with pre-diabetes, whereas there was a risk trend between 'meat' pattern and T2DM. High consumption of meat, especially for red meat which contains high amounts of saturated fat and cholesterol, was associated with an increased risk of obesity, an important risk factor for T2DM[33]. Meanwhile, higher intakes of red meat may result in more absorption of haem iron[34]. Previous studies have also demonstrated that body iron overload may induce insulin resistance and increase the risk of T2DM[35]. Worsely, advanced glycation of high-fat products and meats can enhance oxidative stress and inflammation, which in turn accelerates insulin resistance and increases the risk of T2DM[36].

The 'grains-nuts-egg' dietary pattern, characterised by high consumption of grains, nuts, egg, beans and milk, reduced the risk of T2DM. However, no such correlation was seen with pre-diabetes. A recent report by Song *et al.* has shown that higher consumption of dairy products[37,38] and nuts[39] was associated with a reduced risk of T2DM[40]. In addition, a dose–response meta-analysis of prospective cohort studies revealed an inverse correlation between dairy foods, particularly yogurt, with T2DM[37]. Some investigators[41] stressed that whole-fat dairy could be detrimental, for that an inverse association between diary food and T2DM was seen most frequently in higher yogurt and low-fat milk intake rather than high-fat milk or other dairy products such as cheeses[37,42]. Our study failed to establish a similar inverse correlation with pre-diabetes since our dairy food consumption category referred to all kinds of dairy foods.

The present study holds several strengths. First, to our knowledge, this is the first study to focus on the relationship between dietary patterns and both risks of pre-diabetes and T2DM among the rural adults in China. Our findings provided valuable information for the primary prevention of T2DM, as well as pre-diabetes, through dietary modifications to the rural Chinese population. Second, this survey is a large-scaled cross-sectional study of its kind in rural China. Third, in our analyses, we have also adjusted for some known and proposed potential confounders in the statistical model. However, some potential limitations still warrant a mention. First, based on the cross-sectional design, we cannot evaluate the causal associations between dietary patterns and the risk of pre-diabetes and T2DM. However, the cross-sectional research reflects the individual exposure and outcome at the time of the investigation, which helps to indicate the risk factors of the disease. Second, the

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Table 4. OR (95 % CI) for pre-diabetes and T2DM according factor scores to by dietary pattern

Groups	Dietary patterns	*n*	Crude*		Model 1†		Model 2‡		Model 3§	
			OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI
Pre-diabetes	Factor 1‖									
	Q1¶	599	1	ref.	1	ref.	1	ref.	1	ref.
	Q2	579	0·943	0·835, 1·065	1·061	0·938, 1·200	1·048	0·925, 1·187	1·047	0·924, 1·186
	Q3	533	0·848	0·750, 0·959	1·029	0·908, 1·167	1·007	0·886, 1·144	1·005	0·884, 1·141
	Q4	492	0·787	0·695, 0·892	1·025	0·901, 1·168	1·005	0·881, 1·146	0·999	0·875, 1·141
	Q5	431	0·678	0·596, 0·771	0·971	0·845, 1·115	0·930	0·808, 1·070	0·919	0·794, 1·063
	P_{trend}		<0·001		0·796		0·384		0·820	
	Factor 2									
	Q1	484	1	ref.	1	ref.	1	ref.	1	ref.
	Q2	510	1·049	0·921, 1·194	0·977	0·857, 1·114	0·991	0·868, 1·131	0·991	0·869, 1·131
	Q3	540	1·120	0·985, 1·274	0·993	0·871, 1·133	1·013	0·887, 1·157	1·011	0·885, 1·155
	Q4	574	1·188	1·046, 1·349	1·017	0·891, 1·161	1·054	0·922, 1·205	1·048	0·916, 1·200
	Q5	526	1·090	0·957, 1·242	0·896	0·780, 1·028	0·947	0·824, 1·089	0·936	0·809, 1·082
	P_{trend}		0·043		0·078		0·411		0·885	
	Factor 3									
	Q1	604	1	ref.	1	ref.	1	ref.	1	ref.
	Q2	627	1·029	0·915, 1·157	1·073	0·953, 1·208	1·072	0·951, 1·209	1·061	0·937, 1·202
	Q3	494	0·790	0·698, 0·895	0·859	0·757, 0·975	0·847	0·745, 0·963	0·833	0·725, 0·957
	Q4	510	0·810	0·716, 0·917	0·893	0·787, 1·014	0·898	0·790, 1·022	0878	0·757, 1·019
	Q5	399	0·616	0·540, 0·703	0·690	0·602, 0·791	0·708,	0·616, 0·813	0·683	0·569, 0·820
	P_{trend}		<0·001		<0·001		<0·001		<0·001	
T2DM	Factor 1**									
	Q1	806	1	ref.	1	ref.	1	ref.	1	ref.
	Q2	824	0·965	0·868, 1·072	1·076	0·966, 1·197	1·053	0·943, 1·175	1·049	0·940, 1·171
	Q3	720	0·841	0·755, 0·936	1·035	0·927, 1·156	1·004	0·896, 1·124	0·988	0·883, 1·107
	Q4	681	0·805	0·722, 0·897	1·094	0·978, 1·225	1·079	0·962, 1·211	1·039	0·925, 1·167
	Q5	623	0·720	0·645, 0·804	1·111	0·987, 1·251	1·094	0·968, 1·235	1·008	0·888, 1·144
	P_{trend}		<0·001		0·068		0·123		0·103	
	Factor 2††									
	Q1	795	1	ref.	1	ref.	1	ref.	1	ref.
	Q2	705	0·883	0·793, 0·984	0·848	0·761, 0·946	0·875	0·783, 0·978	0·877	0·781, 0·976
	Q3	700	0·882,	0·792, 0·983	0·837	0·749, 0·936	0·859	0·766, 0·962	0·843	0·752, 0·945
	Q4	705	0·886	0·795, 0·987	0·835	0·745, 0·935	0·871	0·775, 0·977	0·835	0·743, 0·939
	Q5	749	0·942	0·846, 1·049	0·872	0·778, 0·979	0·919	0·817, 1·034	0·845	0·747, 0·956
	P_{trend}		0·343		0·009		0·117		0·125	
	Factor 3‡‡									
	Q1	862	1	ref.	1	ref.	1	ref.	1	ref.
	Q2	810	0·920	0·830, 1·019	0·954	0·860, 1·059	0·966	0·868, 1·075	0·904	0·809,1·009
	Q3	740	0·819	0·737, 0·909	0·870	0·781, 0·968	0·884	0·792, 0·987	0·794	0·704, 0·894
	Q4	652	0·719	0·645, 0·801	0·772	0·690, 0·862	0·793	0·707, 0·889	0·682	0·598, 0·777
	Q5	590	0·634	0·567, 0·708	0·698	0·622, 0·784	0·742	0·659, 0·835	0·582	0·497, 0·682
	P_{trend}		<0·001		<0·001		<0·001		<0·001	

T2DM, type 2 diabetes mellitus.
*Crude: unadjusted.
†Model 1: adjusted for age, region, gender, education level, marital status and per capita monthly income.
‡Model 2: further adjusted for BMI, smoking, alcohol drinking, physical activity and family history of diabetes based on model 1.
§Model 3: further adjusted for energy based on model 2.
‖Factor scores were divided into quartiles.
¶For the quintiles of each dietary pattern, the first quintile (Q1) was considered as the reference group.
**Factor 1, 'meat' pattern.
††Factor 2, 'grains-nuts-egg' dietary pattern.
‡‡Factor 3, 'vegetables-staple-fruits' pattern.

definition of T2DM based on FPG and HbA1C was flawed. Thus, additional diagnostic tests were needed in future research. Third, factor analysis, which was used for data reduction, has limitations. The definition of the dietary patterns, including determination on number of factors, the type of rotation, as well as the interpretation and naming of the factors, involves subjective decisions (may not be so objective)[31]. We used rotation in the analysis to make the extracted factors more explanatory. Fourth, we had no further calculation of nutrients, since FFQ was collected according to food group. For further researches, we will evaluate the reliability and validity of the amounts of nutrients obtained through FFQ by calculating the nutrient weighting coefficients for each food group based on data from the 3-d 24 h-dietary review of a small sample. Fifth, Differences between the group with normal glucose metabolism and the group with diabetes may reflect changes in diet as a result of the diabetes diagnosis. We lack the investigation of newly diagnosed diabetes; nevertheless, we investigated the diet of patients with pre-diabetes, which provides a reference for the prevention of diabetes on dietary precautions.

Conclusions

The 'vegetables-staple-fruits' pattern is beneficial for reducing risk of pre-diabetes or T2DM. People with pre-diabetes should consume more fruits and vegetables instead of meat or eggs/milks. Although a higher consumption of 'grains-nuts-egg' dietary patterns may be associated with a reduced risk of T2DM, excessive intakes should be avoided. This study may provide a reference for the prevention of diabetes on dietary precautions.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980021000227

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