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Food intake patterns are associated with the risk of impaired glucose and insulin homeostasis: a prospective approach in the Tehran Lipid and Glucose Study

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Abstract

Objective: To investigate the association of major dietary patterns with the risk of impaired glucose and insulin homeostasis during a 3-year follow-up.

Design: Fasting serum insulin (FSI), fasting (FSG) and 2 h serum glucose (2h-SG) were measured at baseline and again after 3 years. Dietary intakes were evaluated using a validated 168-item semi-quantitative FFQ and major dietary patterns were obtained using principal component analysis. Logistic regression models were used to estimate the occurrence of impaired fasting glucose (IFG), impaired glucose tolerance (IGT), pre-diabetes (IGT/IFG), β-cell dysfunction and hyperinsulinaemia across tertiles of dietary patterns, with adjustment for potential confounding variables.

Setting: Tehran Lipid and Glucose Study.

Subjects: Iranian men and women (*n* 904).

Results: Mean age of participants was 38·7 (SD 11·3) years and 44·6 % were men. Major dietary patterns were Western, traditional and healthy, which explained 25·2 % of total variance in food intake. There was a positive association between Western and traditional scores with 3-year change in 2h-SG, while the healthy pattern was negatively related to 3-year changes in FSG, 2h-SG, FSI and homeostasis model assessment of insulin resistance. Highest compared with the lowest tertile of the Western dietary pattern was accompanied by a higher risk for development of IGT (OR = 3·09; 95 % CI 1·28, 7·50); a higher score on the healthy dietary pattern was associated with a significantly reduced risk of hyperinsulinaemia (OR = 0·53; 95 % CI 0·28, 0·94).

Conclusions: Our findings showed that adherence to a Western dietary pattern may be a risk factor for the development of IGT, while a healthy dietary pattern may prevent hyperinsulinaemia.

Keywords
Impaired fasting glucose
Impaired glucose tolerance
Dietary pattern
Insulin homeostasis

Impaired fasting glucose (IFG) and impaired glucose tolerance (IGT), intermediate states of impaired glucose regulation in a range of normal glucose homeostasis to type 2 diabetes mellitus, are common glucose disorders that are associated with increased risk of diabetes and its complications as well as CVD[1,2]. β-Cell dysfunction and hyperinsulinaemia are also critical determinants and early stages for the development of type 2 diabetes mellitus[3]. However, integration between social, behavioural, cultural, physiological, metabolic and genetic factors has been found to be involved in the development of dysglycaemia and hyperinsulinaemia. It is widely believed that dietary factors are important in prevention and progression of these metabolic disorders[4–9]. Relatively limited nutritional epidemiological research has been conducted to examine long-term effects of diet on glucose and insulin homeostasis and few data are available from non-Western countries, particularly from the Middle East.

It has been suggested that adherence to a diet rich in fruits, vegetables, whole grains and reduced-fat dairy protects against insulin resistance phenotypes including IFG and IGT, whereas regular consumption of refined grains, high-fat dairy, confectionery, candy and sugar-sweetened beverages – main characteristics of a Western

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dietary pattern – accelerates impaired glucose and insulin regulation[10–13].

Bearing in mind the fact that different dietary behaviours and cultures lead to substantial differences in dietary patterns among populations, investigation of the potential effects of specific dietary patterns of different populations on metabolic disorders seems to be essential. Dietary intake of the Middle Eastern population is based mainly on some staple foods such as white rice and bread, and is characterized by large portion sizes and greater energy intakes from carbohydrates, refined grains and hydrogenated fats[14].

Considering the limited data regarding Iranian dietary patterns and metabolic disorders, and substantial economic, social and lifestyle changes along with a rapid nutrition transition, this challenging issue should be evaluated among the Iranian population. With the aim of identifying potential effects of different major dietary patterns among the Iranian population on glycaemic and insulinaemic states over time, we therefore conducted the current investigation in a large, representative Iranian population who participated in the Tehran Lipid and Glucose Study during 2006–2011.

Methods

Study population

The present study was conducted within the framework of the Tehran Lipid and Glucose Study, an ongoing community-based prospective study being conducted to investigate and prevent non-communicable diseases in a representative sample in district 13 of Tehran, the capital city of Iran[15]. The current analysis was conducted on adult men and women, with complete data on demographics, anthropometrics, biochemical and dietary measurements, who participated in the third (2006–2008) and fourth (2009–2011) examination rounds of the Tehran Lipid and Glucose Study. Participants with diagnosed type 2 diabetes mellitus at baseline examination, who had implausible energy intake (<3347 kJ/d (<800 kcal/d) or ≥17 573 kJ/d (≥4200 kcal/d)), who were on a specific diet or who had no follow-up information on anthropometric and biochemical measurements at the follow-up examination were excluded from the study; and final analysis of data was performed for 904 participants. The mean duration of follow-up was approximately 3 years.

Written informed consent was obtained from all participants and the study protocol was approved by the Ethics Research Council of the Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences.

Demographic, anthropometric and blood pressure measures

Trained interviewers collected information using pre-tested questionnaires. At baseline and after 3 years of follow-up, demographic, anthropometric and biochemical measures were assessed. Smoking status was obtained using face-to-face interviews. Physical activity level was evaluated using the questionnaire of Kriska *et al.*[16] to obtain frequency and time spent in light-, moderate-, high- and very-high-intensity activities according to the list of common daily life activities over the past year; physical activity levels were expressed as metabolic equivalent hours per week (MET × h/week). Weight was measured to the nearest 100 g using digital scales, while the participant was minimally clothed, without shoes. Height was measured to the nearest 0·5 cm, in a standing position without shoes, using a tape meter. BMI was calculated as weight divided by the square of height (kg/m^2). Waist circumference was measured to the nearest 0·1 cm (at anatomical landmarks), at the widest portion, over light clothing, using a soft tape meter, without any pressure to the body. Blood pressure was measured by a trained physician; briefly, after 15 min rest in a sitting position, blood pressure was measured twice on the right arm using a standard mercury sphygmomanometer with an interval of at least 30 s. Each participant's blood pressure was estimated based on the average of the two separate measurements.

Biochemical measures

Fasting blood samples were taken from all study participants after a 12–14 h fast. Fasting serum insulin (FSI) was determined by electrochemiluminescence immunoassay using Roche Diagnostics kits and the Roche/Hitachi Cobas e-411 analyser (Roche Diagnostics Deutschland GmbH, Mannheim, Germany). The intra- and inter-assay CV for insulin were 1·2 and 3·5 %, respectively. Fasting serum glucose (FSG) was measured by the enzymatic colorimetric method using glucose oxidase. The standard 2 h serum glucose (2h-SG) test was performed for all individuals who were not on anti-diabetes drugs. Inter- and intra-assay CV of glucose assays was <5 %. Analyses were performed using Pars Azmoon kits (Pars Azmoon Inc., Tehran, Iran) and a Selectra 2 auto-analyser (Vital Scientific, Spankeren, Netherlands). Inter- and intra-assay CV of all assays was <5 %.

Definition of terms

Homeostatic model assessment of insulin resistance, β-cell function and insulin sensitivity were calculated as follows: HOMA-IR = [fasting insulin (μU/ml) × fasting glucose (mmol/l)]/22·5, HOMA-B = [20 × fasting insulin (μU/ml)]/[fasting glucose (mmol/l) − 3·5], and HOMA-S = 1/HOMA-IR × 100. These indices have been developed as simple, inexpensive and validated alternative tools for assessment of insulin homeostasis in epidemiological studies[17,18].

In the present study, β-cell dysfunction and hyperinsulinaemia were defined according to the new developed optimal cut-off points: HOMA-B ≤ 86·2 and

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67·1 for women and men, respectively and FSI ≥ 11·13 and 9·16 μU/ml in women and men, respectively[19].

IFG was defined as an elevated FSG level (100–126 mg/dl) and IGT was defined as an elevated 2h-SG concentration (140–199 mg/dl); pre-diabetes state was also defined as having at least one of IFG or IGT[20].

Dietary assessment

A 168-item FFQ was used to assess typical food intake over the previous year, at the first examination. The validity and reliability of the FFQ were previously assessed in a random sample, by comparing the data from two FFQ completed 1 year apart and by comparing the data from the FFQ with twelve 24 h dietary recalls, respectively. The validity and reliability of the FFQ for total dietary fat were acceptable; the correlation coefficients between the FFQ and multiple 24 h dietary recalls were 0·59 and 0·38, and those between the two FFQ were 0·43 and 0·42, in males and females, respectively[21]. A study of the reliability, comparative validity and stability of dietary patterns derived from the FFQ also showed that there was a reasonable reliability and validity of the dietary patterns among the population over time[21]. Trained dietitians asked participants to designate their intake frequency for each food item consumed during the past year on a daily, weekly or monthly basis. Portion sizes of consumed foods reported in household measures were then converted to grams. Energy and nutrient contents of foods and beverages were analysed using the US Department of Agriculture food composition table because the Iranian food composition table is incomplete and has limited data on nutrient contents of raw foods and beverages[22]. Finally, dietary intakes of participants including dietary energy and energy density, macronutrients, micronutrients and food groups were determined. Twenty-two separate food groups were defined for factor analysis according to nutrient profiles and previous literature.

Statistical methods

After adjustment of food groups for total energy intake using the residual method, principal component analysis with varimax rotation, based on twenty-two food groups, was used to determine major dietary patterns. Considering eigenvalues >1, the scree plot and the interpretability of the factors, three factors were obtained. Food groups with absolute component loading ≥0·30 were selected to describe the dietary pattern although all food items contributed to the calculation of dietary pattern scores. The Kaiser–Mayer–Olkin statistic, considered a measure of sampling adequacy, was 0·74, which indicated a good appropriateness of factor analysis. The derived dietary patterns were defined according to our interpretation of the data and of the recent literature. Factor scores of the participants were calculated as the sum of multiplying the intakes of the standardized food groups by their respective factor loadings on each pattern. Dietary pattern scores were categorized into tertiles.

Demographics, anthropometrics and biochemical values of the participants with and without IGT were compared by the independent-samples *t* test for continuous variables or the χ^2 test for dichotomous variables.

A univariate analysis was performed for each potential confounding variable, including age (years), sex (male/female), smoking (yes/no), BMI (kg/m^2), use of medications (yes/no), physical activity (MET × h/week), total energy intake (kcal/d), and dietary intakes of total fat (% of energy), carbohydrates (% of energy) and protein (% of energy); variables with $P_E < 0{\cdot}2$ in the univariate analysis were selected for the multivariable models, where P_E (*P* value for entry) determines which variables should be included in the final multivariable model.

The linear association of dietary pattern scores with changes in glucose and insulin parameters during the 3-year follow-up, calculated as [(follow-up measure − baseline measure)/baseline measure] ×100, was assessed using linear regression models with adjustment for potential confounding variables.

To estimate the association of dietary pattern scores with the occurrence of impaired glucose and insulin homeostasis in each tertile category of dietary pattern, participants with each metabolic disorder at baseline were excluded from the analysis. Accordingly, the multivariable logistic regression models, adjusted for the above-mentioned potential confounders, were conducted on 817 participants for IFG, 844 participants for IGT, 794 participants for pre-diabetes state, 728 participants for β-cell dysfunction and 605 participants for hyperinsulinaemia.

All analyses were conducted using the statistical software package SPSS Version 16·0 and *P* values <0·05 were considered significant.

Results

Mean age of participants was 38·7 (SD 11·3) years and 44·6 % were men. Baseline characteristics of the participants according to pre-diabetes status are presented in Table 1. Participants who developed IFG/IGT during the follow-up were more likely to be older, had higher BMI, waist circumference, systolic and diastolic blood pressures, and higher values of FSI, FSG, 2h-SG, HOMA-IR and HOMA-B (*P* for all <0·05). A higher prevalence of hyperinsulinaemia (40·9 *v.* 30·5 %, $P < 0{\cdot}05$) was observed at baseline in participants with development of IFG/IGT. There were no significant differences in total energy, carbohydrates, total fat and protein intakes, or in dietary pattern scores between the participants at baseline.

Table 2 presents three major dietary patterns, Western, traditional and healthy, extracted according to factor analysis. These dietary patterns overall explained 25·2 %

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Table 1 Baseline characteristics of the participants according to pre-diabetes status after the follow-up; Iranian men and women (*n* 794), Tehran Lipid and Glucose Study, 2006–2011

	Pre-diabetes^{-}		Pre-diabetes^{+}		
	Mean	SD	Mean	SD	*P* value
Age at baseline (years)	37·7	10·7	44·8	10·9	0·001
Men (%)	44·6		38·2		0·21
Smoking (%)	10·2		14·8		0·19
Physical activity (MET × h/week)	35·8	52·0	32·3	42·8	0·63
BMI (kg/m^2)	26·6	4·8	29·2	4·5	0·001
Waist circumference (cm)	88·1	13·1	94·2	8·9	0·001
Systolic blood pressure (mmHg)	108	13·9	112	17·9	0·021
Diastolic blood pressure (mmHg)	72·2	10·1	75·9	11·1	0·009
Fasting serum insulin (mg/dl)	8·3	4·7	9·3	6·3	0·021
Fasting serum glucose (mg/dl)	83·5	7·8	87·7	8·5	0·001
2 h Serum glucose (mg/dl)	87·0	19·5	99·7	19·5	0·001
HOMA-IR	1·85	1·10	2·26	1·50	0·010
HOMA-B	126	87	102	91	0·40
HOMA-S	75·0	45·0	67·2	35·2	0·021
β-Cell dysfunction (%)	39·3		42·6		0·51
Hyperinsulinaemia (%)	30·5		40·9		0·02
Dietary pattern scores					
Western	0·018	0·91	0·084	1·83	0·64
Traditional	−0·008	0·98	0·038	1·24	0·73
Healthy	−0·002	1·00	−0·187	0·66	0·06
Energy intake (kJ/d)	9544	2992	9092	2909	0·27
Energy intake (kcal/d)	2281	715	2173	695	0·27
Carbohydrates (% of energy)	57·6	7·1	58·8	7·8	0·22
Total fat (% of energy)	31·3	6·9	29·7	7·6	0·09
Protein (% of energy)	13·5	2·3	13·8	2·5	0·16

MET, metabolic equivalent of task; HOMA-IR, homeostatic model assessment of insulin resistance; HOMA-B, homeostatic model assessment of β-cell function; HOMA-S, homeostatic model assessment of insulin sensitivity.

Table 2 Component loadings of food groups for major dietary patterns among Iranian men and women, Tehran Lipid and Glucose Study, 2006–2011

	Dietary pattern		
	Western	Traditional	Healthy
Refined grains	–	**0·39**	−0·24
Fast foods	**0·57**	–	–
Potato	–	**0·57**	–
Salty snacks	**0·59**	–	0·21
Mayonnaise	**0·51**	–	–
Soft drinks	**0·64**	–	–
Eggs	–	**0·45**	–
Vegetables	–	0·25	**0·53**
Whole grains	−0·28	0·24	–
Fruits (fresh and dried)	–	–	**0·63**
White meats (fish and poultry)	–	**0·30**	0·23
High-fat dairy	0·28	–	0·27
Low-fat dairy	–	–	**0·45**
Jams and compotes	–	–	–
Vegetable oils	–	–	**0·45**
Hydrogenated oils	0·26	**0·34**	–
Confectionery	**0·33**	**0·35**	–
Red meats	–	**0·45**	–
Organ meats	0·23	–	–
Tea and coffee	–	**0·40**	–
Nuts and seeds	–	–	**0·53**
Legumes	–	**0·50**	0·22
Variance* (%)	12·6	6·7	5·9

Values are factor loadings of food patterns measured by factor analysis (*n* 802). Absolute values <0·2 are excluded from the table for simplicity. Absolute values ≥0·30 are highlighted in bold font to give a better description of dietary patterns.
*Eigenvalues > 1.

of the total variance in food intake (Western 12·6 %, traditional 6·7 %, healthy 5·9 %). The Western dietary pattern was characterized by higher loadings of fast foods, salty snacks, mayonnaise, soft drinks and confectionery, whereas refined grains, potato, eggs, fish and poultry, legumes, hydrogenated fats, confectionery, red meats, tea

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and coffee were major components loading on the traditional dietary pattern. Components loading on the healthy dietary pattern were vegetables, fresh and dried fruits, low-fat dairy, vegetable oils, nuts and seeds.

The linear associations of dietary pattern scores with changes in glucose and insulin parameters during the 3-year follow-up are presented in Table 3. Both Western and traditional pattern scores had a positive association with 2h-SG ($\beta = 2{\cdot}46$; 95 % CI 0·13, 4·79 and $\beta = 2{\cdot}07$; 95 % CI −0·61, 4·76, respectively). A significant negative association between traditional dietary pattern score and 3-year change in HOMA-S was also observed ($\beta = -4{\cdot}24$; 95 % CI −8·39, −0·10). Healthy pattern score was negatively related to 3-year changes in FSG, FSI, 2h-SG and HOMA-IR; moreover, a borderline positive association between healthy score and HOMA-S was observed ($\beta = 3{\cdot}04$; 95 % CI −0·54, 6·63).

Table 4 shows the results of logistic regression analysis of dietary patterns and the risk of development of impaired glucose and insulin homeostasis after 3 years of follow-up. After adjustment for all potential confounders, the highest compared with the lowest tertile of the Western dietary pattern was accompanied by higher risk for development of IGT (OR = 3·09; 95 % CI 1·28, 7·50); no significant association was observed between Western dietary pattern score and the incidence of IFG, IFG/IGT, β-cell dysfunction or hyperinsulinaemia. The traditional dietary pattern had no significant association with the incidence of impaired insulin and glucose homeostasis. A non-significant reduced risk of IFG, IGT, IFG/IGT and β-cell dysfunction was observed in the highest tertile of the healthy dietary pattern compared with the lowest; higher score on the healthy dietary pattern was also associated with a significantly reduced risk of hyperinsulinaemia (OR = 0·53; 95 % CI 0·28, 0·94).

Discussion

Our findings in the present prospective study indicate that different dietary patterns have different effects on glucose and insulin homeostasis. The dietary pattern characterized by higher loadings of processed foods, salty snacks, mayonnaise, soft drinks and confectionery was related to an increasing trend of 2 h glucose levels and an elevated risk of IGT after 3 years of follow-up. Adherence to the traditional pattern with higher loadings of refined grains, potato, eggs, fish and poultry, legumes, hydrogenated fats, confectionery, red meats, tea and coffee was negatively related to insulin sensitivity index and had a borderline positive association with 2 h glucose levels. On the other hand, the healthy pattern typified by frequent consumption of vegetables, fresh and dried fruits, low-fat dairy, vegetable oils, nuts and seeds was accompanied with decreasing trends of both fasting and postprandial glucose and insulin levels as well as insulin resistance index; greater adherence to the healthy pattern had also a preventive effect against the development of hyperinsulinaemia.

To the best of our knowledge, limited data are available on the relationship of dietary patterns with impaired glucose and insulin homeostasis; previous studies have focused mainly on the risk of type 2 diabetes mellitus. It has been found that some healthy dietary patterns such as a prudent pattern, characterized by higher loadings of fruits and vegetables and particularly high in green leafy vegetables, was associated with a reduced risk of type 2 diabetes mellitus[23,24]. In a population-based prospective study of 64 191 middle-aged women in urban Shanghai, Villegas *et al.* indicated that among three major dietary cluster patterns including 'staple foods', 'dairy milk' and 'alcohol-processed foods', assessed by using *k*-means cluster analysis, a dietary pattern low in staple foods (rice, noodles, steamed bread, and bread) along with high dairy milk intakes was associated with a lower risk of type 2 diabetes mellitus[25]. In the Nurses' Health Study, a dietary pattern high in sugar-sweetened soft drinks, refined grains, soft drinks and processed meat, but low in wine, coffee, cruciferous vegetables and yellow vegetables, was associated with an increased risk of type 2 diabetes mellitus[26].

A recent cross-sectional study among a Chinese population reported that the risk of IFG was higher in the

Table 3 Linear associations of dietary pattern scores with 3-year changes in glucose and insulin homeostasis parameters among Iranian men and women, Tehran Lipid and Glucose Study, 2006–2011

	Western dietary pattern		Traditional dietary pattern		Healthy dietary pattern	
	Regression coefficient β	95 % CI	Regression coefficient β	95 % CI	Regression coefficient β	95 % CI
Fasting serum glucose	0·69	−0·11, 1·50	0·86	−0·09, 1·81	−1·26	−2·09, −0·44
2 h Serum glucose	2·46	0·13, 4·79	2·07	−0·61, 4·76	−3·71	−6·05, −1·38
Fasting serum insulin	2·91	−1·57, 7·40	2·69	−2·57, 7·97	−4·91	−9·47, −0·39
HOMA-IR	1·89	−3·77, 7·56	5·28	−1·35, 11·3	−5·99	−11·7, −0·23
HOMA-B	0·37	−3·03, 3·78	−1·57	−5·56, 2·42	−1·43	−4·88, 2·03
HOMA-S	0·85	−2·69, 4·39	−4·24	−8·39, −0·10	3·04	−0·54, 6·63

HOMA-IR, homeostatic model assessment of insulin resistance; HOMA-B, homeostatic model assessment of β-cell function; HOMA-S, homeostatic model assessment of insulin sensitivity.
Linear regression models were used with adjustment for age, sex, BMI, physical activity and total energy intake.

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Table 4 Odds of pre-diabetes states, β-cell dysfunction and hyperinsulinaemia across tertile categories of dietary patterns among Iranian men and women, Tehran Lipid and Glucose Study, 2006–2011

	Dietary pattern														
	Western pattern					Traditional pattern					Healthy pattern				
	T1	T2		T3		T1	T2		T3		T1	T2		T3	
	Ref.	OR	95 % CI	OR	95 % CI	Ref.	OR	95 % CI	OR	95 % CI	Ref.	OR	95 % CI	OR	95 % CI
IFG															
Model 1	1·00	0·85	0·53, 1·37	0·91	0·56, 1·47	1·00	1·09	0·67, 1·77	1·11	0·69, 1·80	1·00	0·95	0·59, 1·52	0·84	0·56, 1·37
Model 2	1·00	0·89	0·54, 1·45	0·92	0·56, 1·52	1·00	1·10	0·67, 1·82	1·19	0·73, 1·94	1·00	0·92	0·57, 1·48	0·80	0·49, 1·32
Model 3	1·00	0·88	0·53, 1·46	0·91	0·53, 1·56	1·00	1·16	0·68, 1·95	1·35	0·73, 2·49	1·00	0·91	0·55, 1·51	0·77	0·43, 1·38
IGT															
Model 1	1·00	2·42	0·99, 5·91	3·45	1·45, 8·21	1·00	1·13	0·54, 2·37	1·75	0·87, 3·52	1·00	1·23	0·59, 2·52	1·34	0·62, 2·90
Model 2	1·00	2·36	0·96, 5·79	3·38	1·41, 8·13	1·00	1·20	0·56, 2·56	1·77	0·86, 3·64	1·00	1·13	0·54, 2·37	1·29	0·59, 2·83
Model 3	1·00	1·67	0·64, 4·37	3·09	1·28, 7·50	1·00	1·17	0·54, 2·51	1·78	0·85, 3·70	1·00	0·87	0·40, 1·83	0·69	0·27, 1·77
IFG/IGT															
Model 1	1·00	1·13	0·71, 1·81	1·27	0·80, 2·04	1·00	1·02	0·65, 1·60	0·97	0·62, 1·53	1·00	1·02	0·65, 1·59	0·85	0·53, 1·35
Model 2	1·00	1·14	0·70, 1·84	1·33	0·84, 2·13	1·00	0·98	0·62, 1·56	1·00	0·62, 1·59	1·00	0·97	0·61, 1·53	0·82	0·51, 1·31
Model 3	1·00	1·13	0·70, 1·85	1·31	0·78, 2·18	1·00	1·02	0·63, 1·65	1·09	0·62, 1·93	1·00	0·87	0·54, 1·42	0·67	0·38, 1·18
β-Cell dysfunction															
Model 1	1·00	0·56	0·36, 0·86	1·02	0·68, 1·53	1·00	1·14	0·76, 1·71	1·14	0·76, 1·70	1·00	1·07	0·71, 1·61	1·11	0·74, 1·67
Model 2	1·00	0·57	0·37, 0·88	1·01	0·67, 1·52	1·00	1·13	0·75, 1·72	1·11	0·73, 1·68	1·00	1·05	0·69, 1·60	1·15	0·76, 1·74
Model 3	1·00	0·60	0·38, 0·94	1·04	0·65, 1·64	1·00	1·04	0·68, 1·61	0·92	0·55, 1·52	1·00	0·92	0·59, 1·45	0·85	0·49, 1·46
Hyperinsulinaemia															
Model 1	1·00	1·19	0·71, 2·00	1·35	0·79, 2·28	1·00	0·77	0·46, 1·28	1·04	0·64, 1·70	1·00	0·64	0·39, 1·06	0·58	0·35, 1·00
Model 2	1·00	1·20	0·71, 2·03	1·36	0·80, 2·31	1·00	0·74	0·44, 1·24	1·00	0·61, 1·65	1·00	0·65	0·39, 1·08	0·56	0·34, 1·02
Model 3	1·00	1·10	0·63, 1·91	1·28	0·71, 2·30	1·00	0·77	0·44, 1·32	1·08	0·88, 2·02	1·00	0·63	0·37, 1·07	0·53	0·28, 0·94

Ref., reference category; IFG, impaired fasting glucose; IGT, impaired glucose tolerance; MET, metabolic equivalent of task.
Logistic regression models were used. Model 1 adjusted for age (years) and sex (men/women). Model 2 made additional adjustment for BMI (kg/m^2), physical activity (MET × h/week) and smoking (yes/no). Model 3 made additional adjustment for total energy intake (kcal/d) and dietary intakes of total fat (% of energy), carbohydrates (% of energy) and protein (% of energy).

highest tertile of the animal offal/dessert pattern (OR = 3·15; 95 % CI 1·87, 5·30) while the vegetables/fruits dietary pattern was negatively associated with the risk of IFG; the animal offal/dessert pattern in that study was high in SFA, cholesterol, Fe and Se, and had a high glycaemic load[27]. Another study on non-diabetic participants in the Framingham Offspring Study revealed that adherence to the 'Soda' pattern in comparison to the 'Fruits, Reduced Fat Dairy and Whole Grains' pattern resulted in higher fasting insulin concentrations; moreover, both the 'Refined Grains and Sweets' and 'Soda' patterns compared with the 'Fruits, Reduced Fat Dairy and Whole Grains' pattern were accompanied with higher 2 h post-challenge insulin[10]; in that study no significant difference was observed in insulin sensitivity index between dietary patterns[10].

The associations we observed for the healthy dietary pattern with improved glucose and insulin parameters during the follow-up time are consistent with previous reports in relation to the favourable effects of dietary patterns such as the Mediterranean diet or the DASH (Dietary Approaches to Stop Hypertension) diet against development of insulin resistance and type 2 diabetes mellitus[8,28]. This supports the notion that a plant-based food pattern with a balanced glycaemic index and glycaemic load, rich in fibre and phytochemicals, would be effective to reduce risk of dysglycaemia and pre-diabetes states.

The association of the traditional dietary pattern with change in insulin sensitivity was one of the important findings of the current investigation. Compared with healthy and Western dietary patterns, which have more similarities among different populations, traditional dietary patterns have mostly unique characteristics and different health outcomes in each population. The traditional dietary pattern in the Iranian population is identified mainly by high consumption of refined grains, eggs, tea, red meats, pickles, hydrogenated fats, sugars, salt and spices[14,29]. Previous studies among the Iranian population showed complicated and contradictory findings regarding the traditional diet which was attributed to the complex nature of this pattern[14,29]; a possible explanation, however, is that higher loads of refined grains and hydrogenated fats are the main foundation of the traditional pattern but the presence of some healthy foods like legumes and whole grains may modulate consequent metabolic outcomes[14]. In our study, the highest compared with the lowest traditional score was accompanied with a borderline greater tendency to dysglycaemia and there was a significant decreasing trend of insulin sensitivity in line with increased traditional pattern score. Considering the direct effect of glycaemic index of the diet on insulin sensitivity[30], the observed effect of the traditional pattern on insulin homeostasis may be explained by the high glycaemic nature of this pattern due

to higher loads of white rice, breads, potato and confectionery.

Our findings should be interpreted considering some points. Assessment of dietary intakes was at only one time point and the dietary patterns were assessed based on food intake data without considering eating behaviours such as meal and snacking pattern. It should be noted that identification of dietary patterns as opposed to a single nutrient or food group approach may provide a more accurate and comprehensive description of actual dietary exposure; however, use of factor analysis for dietary data reduction has also been criticized due to its subjectivity in nature and limited generalizability to other populations. In fact, utilization of factor analysis is based on arbitrary decision-making processes for food group assignments, number of retained factors, method of rotation and labelling of components. Lack of data on postprandial levels of insulin to calculate the disposition index and accurately justify insulin homeostasis parameters was a limitation for explanation of the observed associations. Regardless of these issues, to our knowledge, the present study is the first to investigate derived dietary patterns in relation to relatively comprehensive parameters of glucose and insulin homeostasis in a non-diabetic Asian population over time. Use of a validated FFQ to assess regular dietary intake and determine major dietary patterns was an important strength of the study.

Conclusion

In conclusion, our findings showed that the dietary pattern loaded heavily on junk and processed foods as well as high-glycaemic-load foods increased the risk of impaired glucose tolerance; on the other hand, the healthy pattern could prevent hyperinsulinaemia as a main prognosis for the development of type 2 diabetes mellitus. The traditional dietary pattern of the Iranian population, which included higher intakes of refined grains, potato, eggs, fish and poultry, legumes, hydrogenated fats, confectionery, red meats, tea and coffee, was not significantly associated with the incidence of dysglycaemia; however, it was negatively related to change in the insulin sensitivity index. The principal implications of the study highlight the importance of dietary patterns in the development and prevention of dysglycaemia and impaired insulin homeostasis.

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