Original Article

Dietary diversity and physical activity associations with lipid indices among Beijingese: A cross-sectional study

Qiao Guo BSc[1,2], Zuchang Ma PhD[2], Changan Zhu PhD[1], Qiang Zeng MD, PhD[3]

[1]*Precision machinery and precision instruments, Institute of Engineering and Science, University of Science and Technology of China, Anhui, P. R. China*
[2]*Institute of Intelligent Machines, Hefei Institutes of Physical Science, Chinese Academy of Sciences, Anhui, P. R. China*
[3]*Institute of Health Management, Chinese People's Liberation Army (PLA) General Hospital, Beijing, P. R. China*

Background and Objectives: To examine the association of dietary diversity and physical activity with lipid-related indices in a Beijing population. **Methods and Study Design:** This cross-sectional study included 21,472 participants (72.3% men) aged 16 to 78 years. Data were obtained through a physical examination that included anthropometric measurements, biochemical tests, and questionnaires. The dietary diversity score (0-8) was calculated according to the baseline consumption frequencies of eight food groups (cereals, fruits, vegetables, meat, eggs, fish, dairy, and legumes). Physical activity level was classified as low, moderate, or high according to International Physical Activity Questionnaire scoring protocol. Abnormalities in lipid-related indices were assessed using the criteria of the National Cholesterol Education Program Adult Treatment Panel III guidelines. **Results:** Compared with individuals with poor dietary diversity (score 0–5), higher dietary diversity was associated with lower risk of abnormal levels of triglycerides and high-density lipoprotein cholesterol. Dairy intake was associated with a lower risk of having a high triglyceride–to–high-density lipoprotein cholesterol ratio after adjusting for potential covariates. Participants with the lowest risk of abnormal lipid profiles were those who had high levels of physical activity. **Conclusions:** Dietary diversity and physical activity level were associated with lipid-related indices. Therefore, to maintain healthy lipid profiles in the general population, improving dietary diversity and physical activity is essential.

Key Words: dietary diversity, physical activity level, lipid-related indices, Beijingers, cross-sectional study

INTRODUCTION

Dyslipidemia has become an emerging public health threat due to its prevalence and association with the development of cardiovascular disease.[1-3] In recent years, the prevalence of dyslipidemia in China has increased rapidly[4] and is expected to lead to an increase of 9.2 million cardiovascular events between 2010 and 2030.[5] As the two most important controllable lifestyle factors in chronic disease management, diet and physical activity have considerable potential effects on lipid profiles.[6,7]

Healthy eating habits and diverse food intake have been known to be beneficial to various chronic conditions and diseases, including dyslipidemia.[8-11] The Dietary Approaches to Stop Hypertension, which recommend a diet rich in fruits and vegetables and limited in saturated fats and cholesterol, has been shown to reduce the concentration of low-density lipoprotein cholesterol (LDL-C).[8,9] A cross-sectional study demonstrated that higher dietary diversity was associated with lower serum triglycerides (TG).[10] Diet has also been reported to be associated with triglyceride–to–high-density lipoprotein cholesterol (TG/HDL-C) ratio.[11] In addition, physical activity improves blood lipids by increasing high-density lipoprotein cholesterol (HDL-C) and lowering TG concentrations.[12-14] The mechanism could be based on the improvement of endothelial function.[15] However, due to China's large area, complex and diverse eating habits are found across regions,[16,17] and information on the association between dietary diversity, physical activity, and lipid-related indices in the Chinese population must be supplemented.

In the present study, we hypothesized that higher dietary diversity and physical activity level are associated with better lipid profiles, because higher dietary diversity may be related to better nutritional balance and increased physical activity may lead to better health outcomes. However, the relative (separate and combined) contributions of varied food intake and physical activity to lipid profiles remain unclear. We performed a cross-sectional study on the Beijing population to examine the associa-

Corresponding Author: Prof. Qiang Zeng, Institute of Health Management, Chinese People's Liberation Army (PLA) General Hospital, No.350, Shushanhu Road, Beijing, P. R. China.
Tel: +86 18226926305
Email: qiangzeng301@126.com
Manuscript received 03 April 2020. Initial review completed 23 April 2020. Revision accepted 10 June 2020.
doi: 10.6133/apjcn.202009_29(3).0023

tions between dietary diversity and physical activity with lipid-related indices.

METHODS

Participants

Screenings was conducted for a total of 24,521 potential participants (the target population) aged 16 to 78 years who received a health examination from August 2012 to July 2015 at the physical examination center of a hospital in Beijing, China. After exclusion of 3,049 individuals due to a lack of data on dietary habits or physical activity, 21,472 participants were included in the study (Figure 1). Written informed consent was obtained from all participants before the examination commenced. This study was conducted in accordance with ethical standards.

Sociodemographic and anthropometric characteristics

Demographic characteristics, lifestyle characteristics, and personal and familial medical history data of the participants were collected using a standard questionnaire through an interview with trained, certified personnel. Alcohol consumption status was divided into three categories: never (never or rarely consuming alcohol), former (used to consume alcohol, but have abstained for over 6 months) and current. In terms of smoking status, participants were classified as nonsmokers, ex-smokers and current smokers. A physical examination was conducted after the interview. Weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, with the participant wearing light clothing and no shoes. Waist circumstance (WC) was measured with minimal respiration at 1 cm above the navel with inelastic tape to the nearest 0.1 cm. Body mass index (BMI) was calculated as weight in kilogram divided by the square of height in meters.

The population-attributable risk percentage (PAR%) was calculated using the formula:

(It - Iu) / It * 100%

where It is the overall incidence rate of sample, and Iu is the incidence rate of non-exposed group. The study data were collected from a physical examination center of a top hospital in Beijing over 3 years. Therefore, the sample could be considered representative of the general population of Beijing.

Dietary data

Dietary composition data from the previous 3 months were obtained through a retrospective diet frequency questionnaire given during a face-to-face interview. The

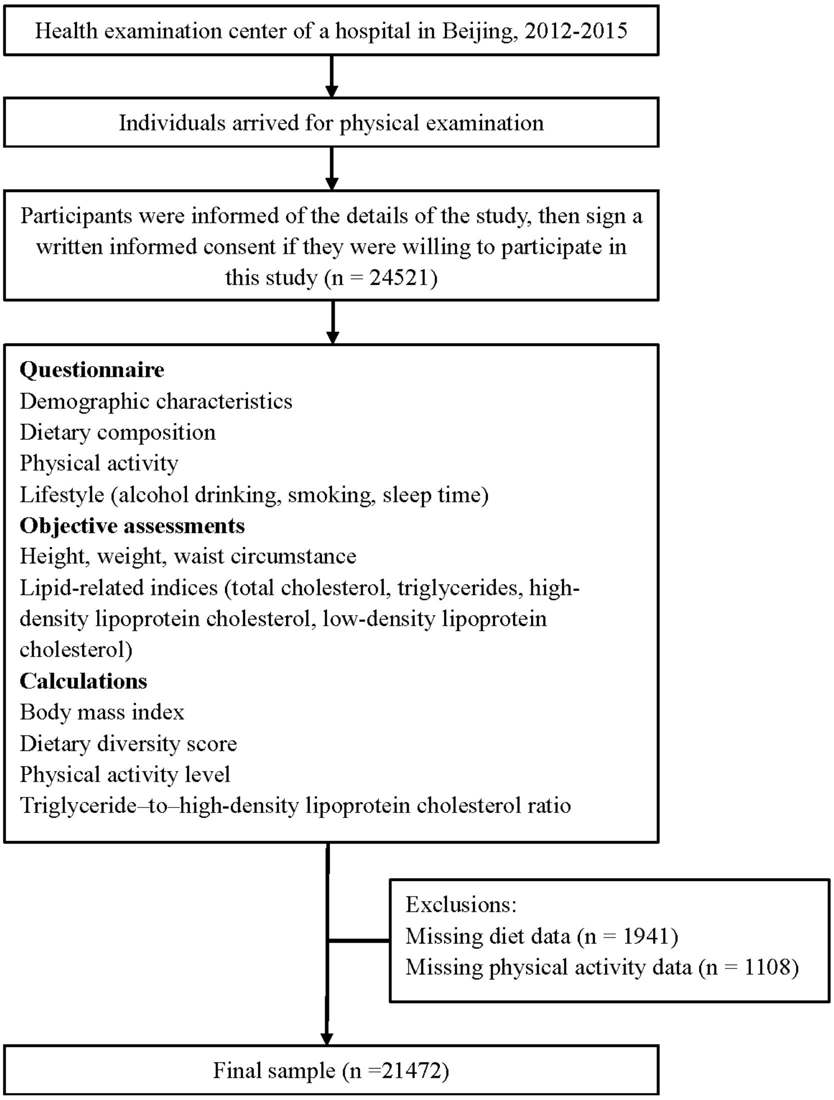

Figure 1. Flow diagram of the study design.

reliability of this questionnaire has been verified.[18] A total of 16 types of food items, food groups and beverages were included in the questionnaire, which contained questions on the frequency of consumption and average consumption of each food item, food group, and beverage. Frequency was defined as the number of times each food item was consumed per week, and the quantity consumed was recorded in "liang", a local unit for weight (1 liang = 50 g), or cups (1 cup = 250 mL). Intake data were converted into averages (in grams or cups per day) for further analysis.

Physical activity level assessment

Physical activity data were recorded as the frequency and duration of walking, moderate physical activity, or vigorous physical activity. Physical activity level was divided into three categories (low, moderate, and high) according to the scoring protocol of the International Physical Activity Questionnaire (IPAQ).[19] Walking, moderate physical activity, and vigorous physical activity were defined as 3.3, 4.0, and 8.0 metabolic equivalents of task (METs), respectively. The physical activity levels of the participants were classified as follows: high, was scored as ≥3 days of vigorous physical activity per week (≥1500 MET-minutes/week) or 7 days of physical activity per week (≥3000 MET-minutes/week); moderate, was scored as ≥3 days of vigorous physical activity per week for ≥20 minutes per day, or ≥5 days of moderate physical activity and walking per week for ≥30 min per day, or ≥5 days of physical activity per week (≥600 MET-minutes/week); and low, indicated failure to meet any of the mentioned criteria.

Biochemical measurements

Venous blood samples were collected in the mornings after at least 10 h of fasting. Total cholesterol (TC), TG, HDL-C and LDL-C concentrations were measured. Serum TC and TG were measured enzymatically using a Hitachi 7150 Automatic-Analyzer (Hitachi, Tokyo, Japan). Serum HDL-C was measured using the same enzymatic method after precipitation with dextran sulfate/magnesium chloride. LDL-C was estimated using the Friedewald formula as follows: mmol/L: LDL-C = TC– HDL-C – (TG ÷ 2.2).[20] The cutoff values frequently used to categorize high TC, TG, and LDL-C were 5.18, 1.70, and 3.37 mmol/L, respectively. According to the clinical definition of metabolic syndrome of the National Cholesterol Education Program Adult Treatment Panel III guidelines, the value frequently used to categorize low HDL-C is 1.04 mmol/L for men and 1.29 mmol/L for women.[21] The participants whose four blood lipid-related indices were within the normal range were categorized as the control group, and the rest of the participants made up the dyslipidemia group.

Statistical analysis

Continuous variables were present as mean ± standard deviation and categorical variables were expressed as quantities and percentages. The Pearson chi-square test and the one-way analysis of variance test were used to evaluate the differences among groups for the categorical and continuous variables, respectively. Odds ratios (ORs) with 95% confidence intervals (CIs) were adjusted for covariates and calculated using univariate and multivariate logistic regression analysis.

The Chinese Nutrition Society recommends the use of dietary diversity score (DDS) to evaluate the dietary balance of Chinese population. DDS covers eight food groups (cereals, fruits, vegetables, meat, eggs, fish, dairy, and legumes). Because the consumption of oils and salt is universal in the Chinese diet and difficult to quantify accurately, these items were not included in assessing DDS. We aimed to construct DDSs based on the principle that selection of food groups for dietary diversity assessment can be driven by a specific purpose.[22] Half of the recommended daily intake for one of the eight food groups was required for a DDS of 1[23]. DDS ranges from 0 to 8. Participants were divided into the poor dietary diversity group (0–5) and good dietary diversity group (6–8) accordingly.

The TG/HDL-C ratio values were divided into quartiles, and a high TG/HDL-C ratio was defined as the highest quartile of TG/HDL-C ratio.[11] All statistical analyses were performed using commercially available software, and the significance level was set at $p<0.05$.

RESULTS

The demographic information and epidemiological characteristics of participants according to the presence or absence of dyslipidemia are presented in Table 1. Men had a higher prevalence of dyslipidemia than women (72.2% versus 60.1%). Smoking and drinking habits were associated with a higher prevalence of dyslipidemia compared with the absence of such habits (smoking 76.0% versus 64.4%; drinking 72.4% versus 62.9%). Participants with dyslipidemia had a higher BMI and greater WC than their normal counterparts. Participants with higher physical activity levels and good dietary diversity had a lower prevalence of dyslipidemia, and participants with dyslipidemia tended to consume more meat and fish and less dairy, vegetables, or fruits. In addition, no significant difference in average daily sleep duration between dyslipidemia and control group was observed. The PAR% results showed that dyslipidemia was more attributed to men (12.6%), overweight and obese participants (19.6%), and participants with an excess WC (26.3%).

Figure 2 shows the consumption rate of each food group by participant characteristics. Overall, the rate of consumption was particularly low for dairy, fruits, and vegetables (22.2%, 52.8%, and 55.2%, respectively). Men consumed significantly less fruits (46.9% versus 68.2%) and vegetables (52.7% versus 61.6%) and more meat (93.9% versus 80.6%) than women. Participants with smoking and drinking habits also consumed less fruits (smoking: 41.8%versus 59.6%; drinking: 46.4% versus 64.0%) and vegetables (smoking: 48.5% versus 58.9%; drinking: 52.5% versus 60.0%) than those without such habits. The consumption rate, stratified by physical activity, BMI, and WC, was significantly different for all food groups (data not shown).

Table 2 presents the associations between dietary diversity, physical activity level and lipid profiles. After adjusting for covariates, namely age, BMI, WC, sex, ethnicity, education, smoking status, and alcohol consumption

Table 1. Characteristics of the participants by dyslipidemia (n=21472)

	Control	Dyslipidemia	PAR%	*p*-value
Total	6693 (31.2)	14779 (68.8)		
Age (years)	47.3±8.65	48.1±7.66		<0.001
Sex				
Male	4314 (27.8)	11202 (72.2)	12.6%	<0.001
Female	2379 (39.9)	3577 (60.1)		
Education				
Primary School	248 (29.6)	589 (70.4)	0.04%	<0.05
High School	2087 (29.7)	4943 (70.3)		
Universities	4358 (32.0)	9247 (68.0)		
Ethnicity				
Han	6355 (31.1)	14054 (68.9)	0.87%	0.65
Other	338 (31.8)	752 (68.2)		
BMI (kg/m^2)	23.9±3.37	25.7±3.17		<0.001
Low (≤18.5)	327 (74.0)	115 (26.0)		<0.001
Normal (18.6-23.9)	3209 (43.0)	4258 (57.0)		
Overweight (24.0-27.9)	2430 (25.1)	7243 (74.9)	19.6%†	
Obesity (≥28.0)	727 (18.7)	3163 (81.3)		
WC (cm)	84.5±10.2	90.1±9.33		<0.001
Normal‡	2904 (49.3)	2992 (50.7)		<0.001
Exceed‡	3789 (24.3)	11787 (75.7)	26.3%	
Alcohol drinking				
Never	2534 (37.1)	4297 (62.9)		<0.001
Former	860 (31.9)	1840 (68.1)		
Current	3299 (27.6)	8642 (72.4)	6.41%	
Smoking				
Never	4360 (35.6)	7893 (64.4)		<0.001
Quit	685 (29.2)	1664 (70.8)		
Current	1648 (24.0)	5222 (76.0)	4.87%	
Physical activity level				
Low	4337 (30.1)	10078 (69.9)	3.18%	<0.001
Moderate	1892 (32.6)	3908 (67.4)		
High	464 (36.9)	793 (63.1)		
Sleep time (hours)	6.65±1.22	6.68±1.25		0.22
Dietary diversity (score)	5.30±1.60	5.29±1.54		0.74
Poor	3416 (30.6)	7759 (69.4)	0.87%	<0.05
Good	3277 (31.8)	7020 (68.2)		
Dietary intake (g/day)				
Cereals	253±128	258±128		<0.05
Fruits	124±103	116±99		<0.001
Vegetables	165±98	160±95		<0.05
Meat	85±64	96±69		<0.001
Eggs	45±33	46±34		<0.05
Fish	39±42	43±44		<0.001
Dairy	106±132	96±131		<0.001
Legumes	33±32	35±34		<0.05

BMI: body mass index; WC: waist circumstance; PAR%: population attributable risk percentage.
Continuous variables are mean ± SD, categorical variables are quantities with percentages in parentheses.
The differences between groups are calculated by Person chi-square test and one-way ANOVA test, significance is defined as $p<0.05$.
†In the calculation of PAR% under BMI classification, overweight and obese people were combined into exposure group.
‡The threshold value of WC exceeding is 85cm for men and 80cm for women.

status, participants with good dietary diversity exhibited significantly lower risks of having high TG (OR, 0.89; 95% CI, 0.84–0.94), low HDL-C (OR, 0.90; 95% CI, 0.85–0.96), and a high TG/HDL-C ratio (OR, 0.89; 95% CI, 0.83–0.95) compared with participants with low dietary diversity. Compared with low levels of physical activity, moderate and high physical activity were significantly associated with reduced risks of having high TC (moderate: OR, 0.93; 95% CI, 0.87–0.99; high: OR, 0.84; 95% CI, 0.74–0.95), high TG (moderate: OR, 0.83; 95% CI, 0.78–0.89; high: OR, 0.68; 95% CI, 0.60–0.78), low HDL-C (moderate: OR, 0.88; 95% CI, 0.82–0.94; high: OR, 0.73; 95% CI, 0.64–0.84), and high TG/HDL-C ratio (moderate: OR, 0.82; 95% CI, 0.76–0.89; high: OR, 0.67; 95% CI, 0.58–0.78). In addition, in the physical activity level category, the individuals with high physical activity had the lowest risks of abnormal lipid profiles.

Table 3 displays the interactions between dietary diversity and physical activity level evaluated by stratified analyses. Dietary diversity interacted significantly with physical activity in effects on TC and LDL-C. For participants with poor dietary diversity, having moderate or high physical activity was associated with significantly reduced risk of TC (moderate: OR, 0.86; 95% CI, 0.78–0.95; high: OR, 0.70; 95% CI, 0.57–0.87) and LDL-C (moderate: OR, 0.87; 95% CI, 0.79–0.96; high: OR, 0.82; 95% CI, 0.67–1.00) abnormalities compared with low physical activity. Participants with low physical activity

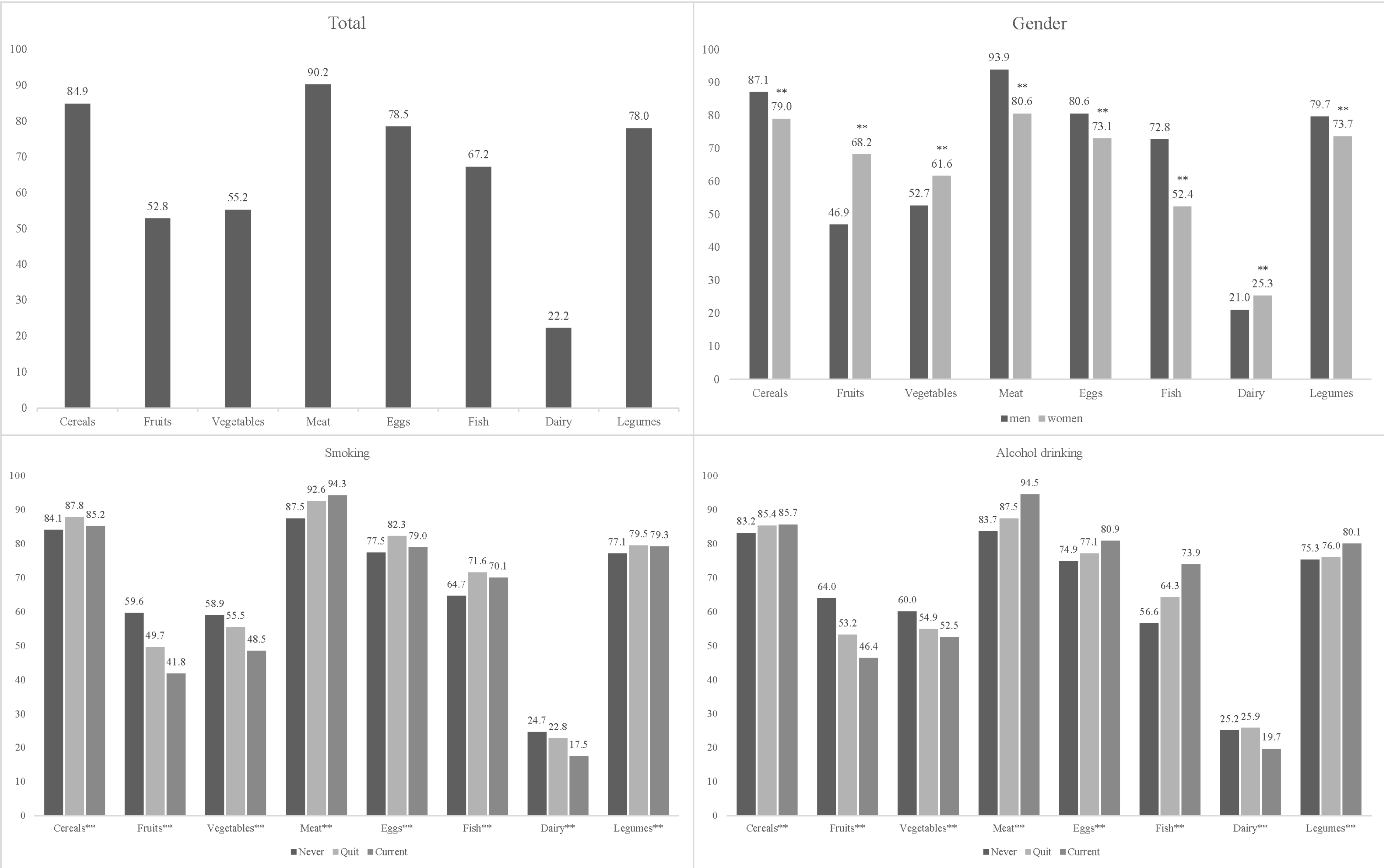

Figure 2. The scoring rate of each food group according to different basic characteristics categories. $^{**}p<0.001$.

Table 2. Abnormal lipid indices by dietary diversity and physical activity ORs (95% CI)

	High TC	R^2	High TG	R^2	Low HDL-C	R^2	High LDL-C	R^2	High TG/HDL-C ratio	R^2
Dietary diversity										
Poor	1 (Reference)	0.02	1 (Reference)	0.17	1 (Reference)	0.09	1 (Reference)	0.02	1 (Reference)	0.16
Good	0.99 (0.93-1.05)		0.89 (0.84-0.94) **		0.90 (0.85-0.96) *		0.97 (0.91-1.02)		0.89 (0.83-0.95) *	
Physical activity										
Low	1 (Reference)	0.02	1 (Reference)	0.17	1 (Reference)	0.09	1 (Reference)	0.02	1 (Reference)	0.17
Moderate	0.93 (0.87-0.99) *		0.83 (0.78-0.89) **		0.88 (0.82-0.94) **		0.97 (0.90-1.03)		0.82 (0.76-0.89) **	
High	0.84 (0.74-0.95) *		0.68 (0.60-0.78) **		0.73 (0.64-0.84) **		0.95 (0.84-1.08)		0.67 (0.58-0.78) **	
p for trend	<0.05		<0.001		<0.001		0.22			

OR: odds ratio; CI confidence interval; TC: total cholesterol; TG: triglyceride; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol.
Adjusted for age (continuous), body mass index (continuous), waist circumstance (continuous), sex, ethnicity, education, alcohol drinking status and smoking status.
*$p<0.05$. **$p<0.001$. The ORs (95% CI) were calculated by logistic regression, significance is defined as $p<0.05$.

Table 3. Interaction between dietary diversity and physical activity on abnormal lipid indices

	High TC	High TG	Low HDL-C	High LDL-C	High TG/HDL-C ratio
Poor dietary diversity					
Physical activity level					
Low	1 (Reference)	1 (Reference)	1 (Reference)	1 (Reference)	1 (Reference)
Moderate	0.86 (0.78-0.95) *	0.87 (0.78-0.96) *	0.87 (0.78-0.96) *	0.87 (0.79-0.96) *	0.84 (0.75-0.94) *
High	0.70 (0.57-0.87) *	0.67 (0.54-0.82) **	0.73 (0.59-0.90) *	0.82 (0.67-1.00) *	0.71 (0.56-0.90) *
Good dietary diversity					
Physical activity level					
Low	0.94 (0.88-1.01)	0.92 (0.86-0.99) *	0.91 (0.84-0.98) *	0.90 (0.84-0.97) *	0.92 (0.85-1.00) *
Moderate	0.94 (0.86-1.02)	0.76 (0.69-0.83) **	0.82 (0.75-0.90) **	0.97 (0.89-1.05)	0.76 (0.68-0.84) **
High	0.89 (0.76-1.04)	0.65 (0.55-0.76) **	0.68 (0.57-0.82) **	0.97 (0.83-1.13)	0.62 (0.51-0.75) **
p for interaction	<0.05	0.80	0.59	<0.05	0.68
R^2	0.02	0.17	0.09	0.02	0.17

OR: odds ratio; CI confidence interval; TC: total cholesterol; TG: triglyceride; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol.
Adjusted for age (continuous), body mass index (continuous), waist circumstance (continuous), sex, ethnicity, education, alcohol drinking status and smoking status.
*$p<0.05$. ** $p<0.001$. The ORs (95% CI) were calculated by logistic regression, significance is defined as $p<0.05$.

had a reduced risk of having high LDL-C when dietary diversity was good (OR, 0.90; 95% CI, 0.84–0.97). Although no statistically significant interaction was detected for TG, HDL-C, or TG/HDL-C ratio, the results showed that participants with good dietary diversity and high physical activity had the lowest risk of having high TG (OR, 0.65; 95% CI, 0.55–0.76), low HDL-C (OR, 0.68; 95% CI, 0.57–0.82) and a high TG/HDL-C ratio (OR, 0.62; 95% CI, 0.51–0.75) compared with participants with poor dietary diversity and low physical activity.

Table 4 shows a further analysis of the relationship between the consumption of each food group and TG/HDL-C ratio. Without covariate adjustment, the intake of cereals, meat, fish, dairy, vegetables, and fruits was significantly associated with TG/HDL-C ratio; consumption of cereals (OR, 1.12; 95% CI, 1.03–1.22), meat (OR, 1.65; 95% CI, 1.47–1.86), and fish (OR, 1.20; 95% CI, 1.12–1.28) were related to an elevated risk of having a high TG/HDL-C ratio, whereas consumption of dairy (OR, 0.73; 95% CI, 0.67–0.79), vegetables (OR, 0.82; 95% CI, 0.77–0.88), and fruits (OR, 0.73; 95% CI, 0.68–0.78) was associated with a lower risk of having a high TG/HDL-C ratio. After adjusting for covariates (age, BMI, WC, sex, ethnicity, education, smoking status, and alcohol consumption status), only dairy consumption remained significantly associated with a lower risk of having a high TG/HDL-C ratio (OR, 0.88; 95% CI, 0.81–0.95).

DISCUSSION

The present study demonstrated the association between dietary diversity, physical activity, and lipid-related indices in a sizable proportion of the Beijing population. Higher dietary diversity and physical activity level were associated with a lower risk of abnormal lipid-related indices. Interactions between dietary diversity and physical activity affected the risks of having high TC and high LDL-C. In addition, dairy intake, found to be seriously insufficient in this sample, was significantly associated with a lower risk of a high TG/HDL-C ratio.

PAR% can reflect the incidence in the general population attribute to the exposed part. The dyslipidemia was more prevalent in men than in women and, as the exposed group, men had a higher PAR%. The differences in lipid profiles between men and women can be attributed to various factors, including estrogens, serum adiponectin, and social life.[24-27] Estrogens have been reported to inhibit HDL-C catabolism by reducing hepatic lipase activity, and to increase LDL-C catabolism by increasing the number of LDL-C receptors.[24-26] A study revealed a higher concentration of serum adiponectin, which is closely associated with favorable lipid profiles, in women than in men.[27] Men in China usually have more opportunities than women to have a diet rich in animal protein and oils through business and social dinners; they also smoke more cigarettes and consume more alcohol than do women.[28] Consistent with findings from previous studies,[29-31] we observed that smoking and drinking habits, excess BMI, and excess WC were associated with dyslipidemia; participants with excess BMI and excess WC showed relatively higher PAR%.

On the basis of the DDS of each food group, we found that Beijing residents consume insufficient quantities of dairy, vegetables, and fruits, especially dairy. This may be related to China's meal culture. In ancient China, due

Table 4. High TG/HDL-C ratio ORs (95% CI) by the score of food groups

		Unadjusted		Adjusted	
	Score	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Cereals					
	0	1 (Reference)		1 (Reference)	
	1	1.12 (1.03-1.22)	<0.05	1.02 (0.93-1.12)	0.72
Fruits					
	0	1 (Reference)		1 (Reference)	
	1	0.73 (0.68-0.78)	<0.001	0.95 (0.89-1.02)	0.11
Vegetables					
	0	1 (Reference)		1 (Reference)	
	1	0.82 (0.77-0.88)	<0.001	0.96 (0.90-1.02)	0.21
Meat					
	0	1 (Reference)		1 (Reference)	
	1	1.65 (1.47-1.86)	<0.001	1.00 (0.88-1.14)	0.98
Eggs					
	0	1 (Reference)		1 (Reference)	
	1	1.03 (0.95-1.11)	0.45	0.92 (0.85-1.00)	<0.05
Fish					
	0	1 (Reference)		1 (Reference)	
	1	1.20 (1.12-1.28)	<0.001	0.95 (0.88-1.02)	0.16
Dairy					
	0	1 (Reference)		1 (Reference)	
	1	0.73 (0.67-0.79)	<0.001	0.88 (0.81-0.95)	<0.05
Legumes					
	0	1 (Reference)		1 (Reference)	
	1	1.06 (0.98-1.15)	0.13	0.98 (0.90-1.06)	0.57

OR: odds ratio; CI confidence interval; TG/HDL-C ratio: triglyceride-to-high-density lipoprotein cholesterol ratio.
The adjusted model was adjusted for age (continuous), body mass index (continuous), waist circumstance (continuous), sex, ethnicity, education, alcohol drinking status and smoking status.
The ORs (95% CI) were calculated by logistic regression, significance is defined as $p<0.05$.

to the underdevelopment of animal husbandry, milk and other dairy products were rarely consumed. The proportion of dairy products in the Chinese diet has only gradually increased in recent decades. Traditionally, the Chinese diet has focused on cereal intake; animal protein consumption has greatly increased with the rise in living standards in recent years, whereas fruit and vegetable consumption and fruits has declined.[32,33] Studies have shown that dairy, fruits, and vegetables are essential components of a balanced diet and are related to positive health outcomes.[34,35] Therefore, increasing the consumption of dairy, fruits, vegetables, and fish in the diet of Beijing residents is critical to public health.

In line with related research, participants with good dietary diversity were at a lower risk of having high TG and low HDL-C compared with those with poor dietary diversity. One study revealed that a higher DDS was associated with lower TG and higher HDL-C concentrations.[36] Participants with moderate and high levels of physical activity had a lower risk of having abnormal TC, TG, and HDL-C. Another study reported that engaging in any form of physical activity was associated with a reduced risk of cardiovascular conditions and diseases, including abnormal lipid profiles, regardless of cardiometabolic risk factors.[37] However, the effect of physical activity on LDL-C was not significant. This may be because according to the IPAQ criteria, fewer individuals have high physical activity exist than have lower levels. Individuals with moderate physical activity must combine diet optimization and weight loss to achieve a considerable reduction in LDL-C.[38]

The interaction analysis revealed significant interactions of dietary diversity and physical activity on TC and LDL-C. With good dietary diversity, the association between physical activity and the risk of high TC was no longer significant. This may be because healthy behaviors tend to be concurrent and because people adopt patterns of health-related behaviors, rather than individual behaviors.[39] People with diverse diets may increase their physical activity in other ways. The IPAQ scoring protocol does not account for unstructured physical activity such as housework and physical activity during commuting. As for LDL-C, although no significant association with dietary diversity or physical activity alone was observed, higher levels of physical activity were significantly associated with a lower risk of high LDL-C in individuals with poor dietary diversity.

In view of the significant association of dietary diversity with TG and HDL-C, we further analyzed the relationship between DDS by food group and TG/HDL-C ratio. TG/HDL-C ratio is a novel lipoprotein index that could be a favorable predictor of cardiovascular disease.[40-42] Our results showed that dairy intake was significantly related to a lower risk of having a high TG/HDL-C ratio, regardless of whether covariates were adjusted. However, as mentioned, dairy intake in the present study population was seriously insufficient. Increased consumption of dairy products is crucial to managing the lipid profiles of Beijing residents and optimizing their dietary structure.

This study has some limitations. First, recall bias may have affected the data on exercise and eating habits, which were obtained by a retrospective questionnaire. To reduce the potential information bias, we ensure that well trained, certified personnel conducted the face-to-face interviews. Second, because leisure physical activity is typically not accurately recorded in daily life, it was not included in the physical activity level evaluation. Well-designed cohort studies are necessary to explore the relationship between leisure physical activity and lipid profiles. This study's strengths include its large sample size and the use of multiple lipid-related indices, which allowed comprehensive exploration of the association of dietary diversity and physical activity with lipid profiles.

In conclusion, this study demonstrated the effect of dietary diversity and physical activity on lipid-related indices, as well as their interactions in a Beijing population. Higher dietary diversity was associated with lower risks of TG and HDL-C abnormalities, and physical activity was associated with TC, TG, and HDL-C. To maintain healthy lipid profiles and prevent the occurrence or progression of dyslipidemia and other chronic diseases in the general population, dietary diversity and physical activity must be promoted. In addition, Beijing residents should increase their dairy consumption.

ACKNOWLEDGEMENTS
The authors would like to thank all the participants in the survey, as well as the staff from the physical examination center of Chinese People's Liberation Army (PLA) General Hospital for their dedicated effort in making this study possible.

AUTHOR DISCLOSURES
The authors declare that there are no conflicts of interest. This work was supported by the major special project of Anhui Science and Technology Department under Grant 18030801133, and Science and Technology Service Network Initiative under Grant KFJ-STS-ZDTP-079.

REFERENCES
1. Joint committee for guideline revision. 2016 Chinese guidelines for the management of dyslipidemia in adults. J Geriatr Cardiol. 2018;15:1-29.
2. Laslett LJ, Alagona P Jr, Clark BA 3rd, Drozda JP Jr, Saldivar F, Wilson SR, Poe C, Hart M. The worldwide environment of cardiovascular disease: prevalence, diagnosis, therapy, and policy issues: a report from the American College of Cardiology. J Am Coll Cardiol. 2012; 60(25 Suppl):S1-S49.
3. World Health Organization. Reducing risks, promoting healthy life. Geneva: World Health Organization; 2002. pp. 248.
4. Pan L, Yang Z, Wu Y, Yin RX, Liao Y, Wang J, Gao B, Zhang L, China National Survey of Chronic Kidney Disease Working Group. The prevalence, awareness, treatment and control of dyslipidemia among adults in China. Atherosclerosis. 2016;248:2-9.
5. Moran A, Gu D, Zhao D, Coxson P, Wang Y, Chen CS et al. Future cardiovascular disease in china: markov model and risk factor scenario projections from the coronary heart disease policy model-china. Circ Cardiovasc Qual Outcomes. 2010;3:243-52.
6. Haskell WL. Exercise-induced changes in plasma lipids and lipoproteins. Prev Med. 1984;13:23-36.
7. Huang J, Frohlich J, Ignaszewski AP. The impact of dietary changes and dietary supplements on lipid profile. Can J Cardiol. 2011;27:488-505.

8. Eckel RH, Jakicic JM, Ard JD, Jesus JM, Miller NH, Hubbard VS et al. AHA/ACC guideline on lifestyle management to reduce cardiovascular risk: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol. 2014;63:2960-84.
9. Sacks FM, Svetkey LP, Vollmer WM, Appel LJ, Bray GA, Harsha D et al. Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. DASH-Sodium Collaborative Research Group. N Engl J Med. 2001;344:3-10.
10. Farhangi MA, Jahangiry L. Dietary diversity score is associated with cardiovascular risk factors and serum adiponectin concentrations in patients with metabolic syndrome. BMC Cardiovascular Disorders, 2018;18:68.
11. Lyu S, Su J, Xiang Q, Wu M. Association of dietary pattern and physical activity level with triglyceride to high-density lipoprotein cholesterol ratio among adults in Jiangsu, China: a cross-sectional study with sex-specific differences. Nutr Res. 2014;34:674-81.
12. Aadahl M, von Huth Smith L, Pisinger C, Toft UN, Glumer C, Borch-Johnsen K, Jorgensen T. Five-year change in physical activity is associated with changes in cardiovascular disease risk factors: the Inter99 study. Prev Med. 2009;48:326-31.
13. Durstine JL, Grandjean PW, Davis PG, Ferguson MA, Alderson NL, DuBose KD. Blood lipid and lipoprotein adaptations to exercise: a quantitative analysis. Sports Med. 2001;31:1033-62.
14. Skoumas J, Pitsavos C, Panagiotakos DB, Chrysohoou C, Zeimbekis A, Papaioannou I, Toutouzas P, Stefanadis C. Physical activity, high density lipoprotein cholesterol and other lipids levels, in men and women from the ATTICA study. Lipids Health Dis. 2003;2:3.
15. Durstine JL, Grandjean PW, Cox CA, Thompson PD. Lipids, lipoproteins, and exercise. J Cardiopulm Rehabil. 2002;22:385-98.
16. Wahlqvist ML, Savige G, Wattanapenpaiboon N. Cuisine and health: a new initiative for science and technology. The ‘Zhejiang Report ‘from Hangzhou. Asia Pacific journal of clinical nutrition. 2004;13:121-4.
17. Zhu YX, Huang J, Zhang ZK, Zhang QM, Zhou T, Ahn YY. Geography and similarity of regional cuisines in China. PLoS One. 2013;8:e79161.
18. Zhao W, Hasegawa K, Chen J. The use of food-frequency questionnaires for various purposes in China. Public Health Nutr. 2002;5:829-33.
19. Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE et al. International Physical Activity Questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35:1381-95.
20. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem. 1972;18:499-502.
21. Kuhar MB. Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III). Circulation. 2001;106:3143-421.
22. Ruel MT. Operationalizing dietary diversity: a review of measurement issues and research priorities. J Nutr. 2003;133: 3911-26. doi: 10.1093/jn/133.11.3911S.
23. Lee MS, Huang YC, Wahlqvist ML. Chewing ability in conjunction with food intake and energy status in later life affects srvival in Taiwanese with the metabolic syndrome. J Am Geriatr Soc. 2010;58:1072-80.
24. Heinzl H, Kaider A. Gaining more flexibility in Cox proportional hazards regression models with cubic spline functions. Comput Methods Programs Biomed. 1997;54: 201-8.
25. Wakatsuki A, Sagara Y. Effects of continuous medroxyprogesterone acetate on lipoprotein metabolism in postmenopausal women receiving estrogen. Maturitas. 1996; 25:35-44.
26. Baker L, Meldrum KK, Wang M, Sankula R, Vanam R, Raiesdana A, Tsai B, Hile K, Brown JW, Meldrum DR. The role of estrogen in cardiovascular disease. J Surg Res. 2003; 115:325-44.
27. Mirinazhad MM, Farhangi MA, Jahangiri L, Yaghoubi A. Serum adiponectin concentrations in relation to lipid profile, anthropometric variables and insulin resistance in patients with metabolic syndrome. Mal J Nutr. 2014;20:283-9.
28. Wang S, Ungvari GS, Forester BP, Chiu HFK, Wu Y, Kou C et al. Gender differences in general mental health, smoking, drinking and chronic diseases in older adults in Jilin province, China. Psychiatry Res. 2017;251:58-62.
29. Li XX, Zhao Y, Huang LX, Xu HX, Liu XY, Yang JJ, Zhang PJ, Zhang YH. Effects of smoking and alcohol consumption on lipid profile in male adults in northwest rural China. Public Health. 2018;157:7-13.
30. Kokkinos PF, Holland JC, Newman R, Fiest-Fite B, Signorino CE, USAF. Physical activity, smoking, alcohol consumption, body mass index, and plasma lipid profiles of military reserve officers. Mil Med. 1989;154:600-3.
31. Vatanparast H, Chilibeck PD, Cornish SM, Little JP, Paus-Jenssen LS, Case AM, Biem HJ. DXA-derived abdominal fat mass, waist circumference, and blood lipids in postmenopausal women. Obesity. 2009;17:1635-40.
32. Wahlqvist ML, Lee MS. Regional food culture and development. Asia Pac J Clin Nutr. 2007;16(Suppl 1):2-7.
33. Yuan M, Lawrence SJL, Wahl T, Bai J. The changing dietary patterns and health issues in China. China Agricultural Economic Review. 2019;11(1):143-159. (In Chinese)
34. Issa C, Darmon N, Salameh P, Maillot M, Batal M, Lairon D. A Mediterranean diet pattern with low consumption of liquid sweets and refined cereals is negatively associated with adiposity in adults from rural Lebanon. Int J Obes (Lond). 2011;35:251-8.
35. Demetriou CA, Hadjisavvas A, Loizidou MA, Loucaides G, Neophytou I, Sieri S, Kakouri E, Middleton N, Vineis P, Kyriacou K. The Mediterranean dietary pattern and breast cancer risk in Greek-Cypriot women: a case-control study. BMC Cancer 2012;12:113-24.
36. Gholizadeh F, Moludi J, Yagin NL, Alizadeh M, Nachvak SM, Abdollahzad H, Mirzaei K, Mostafazadeh M. The relation of dietary diversity score and food insecurity to metabolic syndrome features and glucose level among pre-diabetes subjects. Prim Care Diabetes. 2018;12:338-44.
37. Gibbs BB, Brancati FL, Chen H, Coday M, Jakicic JM, Lewis CE, Stewart KJ, Clark JM. Effect ofimproved fitness beyond weight loss on cardiovascular risk factors in individuals with type 2 diabetes in the look AHEAD study. Eur J Prev Cardiol. 2014;21:608-17.
38. Leon AS, Sanchez OA. Response of blood lipids to exercise training alone or combined with dietary intervention. Med Sci Sports Exerc. 2001;33(Suppl):S502-15.
39. Venkataraman K, Wee HL, Ng SHX, Rebello S, Tai ES, Lee J, Tan CS. Determinants of individuals’ participation in integrated chronic disease screening in Singapore. J Epidemiol Community Health 2016;70:1242e50.
40. Sone H, Tanaka S, Iimuro S, Ishibashi S, Oikawa S, Shimano H et al. Comparison of various lipid variables as

predictors of coronary heart disease in Japanese men and women with type 2 diabetes: subanalysis of the Japan Diabetes Complications Study. Diabetes Care. 2012;35: 1150-7.

41. Barzi F, Patel A, Woodward M, Lawes CM, Ohkubo T, Gu D et al. A comparison of lipid variables as predictors of cardiovascular disease in the Asia Pacific region. Ann Epidemiol. 2005;15:405-13.
42. Dogan C, Bayram Z, Karagoz A, Bakal RB, Erdogan E, Yilmaz F et al. Is elevated triglyceride high density lipoprotein cholesterol ratio a risk factor that causes acute coronary syndrome to appear earlier? Bratisl Lek Listy. 2019;119:770-5.