**Dietary patterns and their associations with metabolic syndrome and predicted 10-year risk of cardiovascular disease in northwest Chinese adults**

A shortened version of the title: Dietary patterns, metabolic syndrome and risk of cardiovascular disease in Chinese adults.

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Abbreviations Used: MetS: metabolic syndrome; CVD: cardiovascular disease; ASCVD: atherosclerotic cardiovascular disease; China-PAR: prediction for ASCVD risk in China; DPs: dietary patterns; RRR: reduced rank regression; PCA: principal component analysis; OR: odd ratio; IDF: International Diabetes Federation criteria; FFQ: food frequency questionnaire; BMI: body mass index; WC: waist circumference; FBG: fasting blood glucose; TG: triglyceride; TC: total cholesterol; HDL-C: high density lipoprotein; LDL-C: low density lipoprotein; SBP: systolic blood pressure; DBP: diastolic blood pressure; MAP: mean arterial blood pressure; SES: social economic status;

**ABSTRACT**

The diet impact on metabolic syndrome(MetS) and cardiovascular diseases has been investigated widely, but few studies investigated the association between dietary patterns(DPs) and the the predicted cardiovascular disease, derived from reduced-rank regression (RRR). The objectives of this study were to derive DPs using RRR and principal component analysis (PCA), and investigate their associations with MetS and estimated 10-year atherosclerotic cardiovascular disease (ASCVD). We used the baseline dataset from the Xinjiang multi-ethnic cohort study in China, collected from June 2018 to may 2019. A total of 14982 subjects aged 35-74 years from Urumqi, Huo Cheng, and Mo Yu were included in the analysis. The 10-year ASCVD risk was estimated using the Chinse ASCVD risk equations. The associations of DPs with MetS and 10-year ASCVD were determined using multivariable logistic regression models.In Urumqi and Mo yu, the increased RRR DP score was associated with a higher odds ratio (OR) of having the MetS and with a higher OR of elevated 10-year ASCVD risk. However, Only the first DP determined by PCA in Urumqi were inversely associated with MetS and elevated 10-year ASCVD risk. The prevalence of MetS and elevated ASCVD risk in urban population is higher than that in rural areas.Our results may help nutritionists develop more targeted dietary strategies to prevent MetS and ASCVD in different regions in China.

**Introduction**

 Metabolic syndrome (MetS) is a cluster of metabolic abnormalities that have been associated with an increased risk of developing cardiovascular diseases (CVDs) [1]. Based on the findings from the China National Health and Nutrition Surveillance (2010-2012), the overall prevalence rate of MetS among Chinese adults was 11.0% [2]. It has been estimated that men with MetS have a three-fold increased risk of CVD [3]. Atherosclerosis is the underlying disease process that may result in atherosclerotic CVD (ASCVD) including myocardial infarction, ischaemic stroke and peripheral arterial disease [4].

Due to the increasing prevalence of metabolic diseases such as obesity and diabetes, ASCVD has been globally considered a serious public health issue. In 2018, an estimated 290 million people had CVDs, and they are also the number one cause of mortality in China, accounting for more than 40% of all deaths [5]. Given the human burden of ASCVD, risk assessment provides guidance to clinicians in preventive interventions. Most risk prediction models derived primarily from Western populations, such as the Pooled Cohort Equations (PCE) [6], might not be suitable for direct application in other ethnic populations. Therefore, in 2016, the sex-specific prediction for ASCVD risk in China (China-PAR) equations for 10-year risk prediction of ASCVD were successfully developed and validated for the Chinese population [7].

Among the influencing factors of CVD, healthy eating has been implicated as a preventive behaviour to reduce the risk of CVD [8-9]. Furthermore, an overall healthy dietary pattern (DP) has also been shown to be associated with reduced CVD risk [10]. Information on mediating pathways/risk factors in diet-disease studies may provide a better understanding of the role of diet in disease development. Cardio-metabolic traits, including the components of the MetS, are typically important predictors for CVD, but have also been implicated in carcinogenics [11]. Reduced rank regression (RRR) can be used to derive DPs that maximally explain variation in a set of predetermined response variables, typically intermediates related to disease risk. Because an a priori hypothesis can be incorporated in the form of response variables, derived DPs may be more readily linked to biological pathways relevant for disease etiology [12]. This is the advantage of RRR over traditional diet pattern principal component analysis (PCA) [13]. DPs derived using PCA tend to explain a high proportion of the variability in dietary intake and hence describe actual DPs of the population [14].

DPs are different by geographical, region, ethnicity, economic status and culture [15-16]. Located in the northwestern border of China, Xinjiang is the largest provincial administrative region in China with an area of 1.66 million square kilometers, accounting for one-sixth of China's total land area. It is customary to call the south of the Tianshan Mountains, south Xinjiang, and the north of the Tianshan Mountains, north Xinjiang. As a multi-ethnic area, 47 ethnic groups live here. For a long time, complex and diverse dietary structures and habits have been formed, and different levels and types of dietary imbalances, have resulted in different prevalence rates of some chronic diseases. At the same time, the imbalance of economic development has caused widespread malnutrition and micro-nutrient deficiencies in rural areas, especially in poor rural areas. According to the International Diabetes Federation criteria (IDF), the age-standardized prevalence of MetS in Xinjiang was 21.33% [17]. To the best of our knowledge, since the establishment of the China-PAR in 2016, it has not been used to predict 10-year risk of ASCVD in Xinjiang population. Few studies have looked at the association of DPs with MetS and the predicted 10-year risk of ASCVD in Xinjiang Uyghur population[18] and none have used RRR. The current studies on DPs related to metabolic disorders using RRR method are mainly carried out in European and American populations. Given the unique and novel strengths of the RRR methodology and its limited application to nutritional epidemiology to date, further studies are needed to improve our understanding of the relationship between RRR-derived DP and MetS and estimated risk of ASCVD. Furthermore, the role of area differences in diet with respect to the association with MetS and ASCVD is still uncertain.

Therefore, the aims of this study were to identify DPs associated with blood metabolism biomarkers and to evaluate the association of DPs with MetS and the predicted 10-year risk of ASCVD in this multi-ethnic population in three different study sites, in northwest China.

**Methods**

**Study design and study population**

The Xinjiang multi-ethnic cohort study (CNC) is a population-based, prospective cohort established from April 2018 to May 2019. A non-probability sampling design method was used to select three specific areas in Xinjiang based on their socioeconomic status, geographical location and ethnic distribution: Urumqi, Huo Cheng, and Mo Yu. As the capital city of Xinjiang, Urumqi has a relatively developed economy. Huo Cheng is located in northern Xinjiang, which is a multi-ethnic living area. Mo Yu is located in southern Xinjiang, about 1450 kilometers away from Urumqi, and the economy is more backward than other areas of Xinjiang. A total of 30,949 adults, aged 35-74 years were enrolled. For the current study, we included only those participants of the CNC with complete information regarding cardio-metabolic traits. We excluded any subject with acute myocardial infarction or stroke and/or diabetes mellitus (based on self-reported diabetes mellitus at baseline and/or use of anti-diabetic drugs). Therefore, 14982 subjects (6098 males and 8884 females) with complete data on diet and cardio-metabolic risk factors were included in this study. Informed consent was obtained from all participants, who were then interviewed in person using structured questionnaires. The study was approved by the institute of traditional Chinese medicine of Xinjiang Uyghur autonomous region (2018XE0108). Detailed information about the CNC study design has been described elsewhere [19] (Figure 1).

**Laboratory Measurements**

Each Participant was invited to provide a fasting blood sample. Fasting blood glucose (FBG) was measured in whole blood and triglyceride (TG), total cholesterol (TC), high density lipoprotein (HDL-C), and low density lipoprotein (LDL-C) were measured in serum. The health service centers of each village in the three survey sites were responsible for the blood glucose and blood lipid detection by automatic biochemical analyzer. The test methods and requirements are based on the national clinical test operating procedures[20].

**Dietary assessment**

Habitual diet over the past year was assessed using the interviewer-administered food frequency questionnaire (FFQ). Referring to the dietary questionnaire of natural population cohort study in northwest China and combining the characteristics of Xinjiang diet, the final FFQ included 127 foods items. The 127 food items were aggregated into 30 food groups based on similarity of nutrient composition and culinary usage. The food items and six food categories: Staple food, including rice, wheat and whole grains; Animal food, including pork, lamb, beef, poultry and products, seafood products, eggs and products of animal viscera, such as offal; Plant based food, including fresh vegetables, fresh fruits, potato, beans and products; Dairy products, including milk, yogurt, other dairy products, butter tea and milk tea; Other food, including pickled /dried vegetables, nuts, red dates, gouji berries, raisins and dried fruits; Soft drinks, including soy milk, pure juice, carbonated drinks, and other sugary drinks. For each food item, participants reported the frequency of habitual consumption but not quantities of food consumption. The frequency of intake was measured using five categories: daily, 4-6 times a week, 1-3 times a week, 1-3 times a month, never or rarely. This FFQ has not been validated yet.

Excluded (n=747)

Receiving diabetes treatment

Excluded (n=2366)

Occurred ASCVD at baseline

Subjects included in the CNC

n=30949

Excluded (n=8306)

No blood lipids detected

Included n=22643

Data available for analysis

n=14982

 Missing data (n=4548)

 · metabolic indicators

· dietary data

**Figure 1. Flow diagram of subjects included in the CNC**

**MetS assessment**

 MetS was defined according to the Chinese Diabetes Society criteria [21]. The presence of ≥3 of the following metabolic risk factors: (1) abdominal obesity: male waist circumference (WC) ≥90cm and female WC ≥85cm; (2) hypertension: systolic blood pressure/ diastolic blood pressure (SBP/DBP) ≥130/85mmHg; (3) high glycerol esteremia: TG ≥ 1.70 mmol/L; (4) low high density lipoproteinemia: fasting HDL-C < 1.04mmol/L; (5) hyperglycemia: FBG ≥ 6.1 mmol/L.

**Estimated 10-year ASCVD risk**

The predicted 10-year risk of a first ASCVD event for adults aged 35 to 74 years was calculated using the China-PAR equation and included the following variables: age (years), concentration of TC (mg/dL), HDL-C (mg/dL), treated or untreated SBP (mmHg), diabetes status (defined here as physician diagnosis), self-reported smoking status (yes, no), body mass index (BMI), WC, geographic region (northern China, southern China), urbanization (urban, rural), and family history of ASCVD (yes, no). Participants with an ASCVD score of＞5% were considered to be at high risk for future ASCVD events. The China-PAR equation has been validated and applied in previous studies [22-23].

**Covariate assessment**

Weight, height and WC were measured by investigators using standard methods. Weight and height were measured while the participants were marginally clothed, without shoes using an SK-X80 (Sonka Corporation, Shen Zhen, China) and recorded to the nearest 0.1kg and 0.1cm. The BMI was calculated as weight in kilograms divided by the square of height in metres. The WC was measured to the nearest 0.1cm at the midpoint between the lower rib and the iliac crest, at the end of normal expiration, while the participants were standing. Blood pressure was measured using a standard mercury sphygmomanometer with the cuff on the right upper arm after 5minutes of rest. Two blood pressure readings taken 5 minutes apart, were recorded, and the mean of the two readings were calculated for SBP and DBP, together with the mean arterial blood pressure (MAP). Face-to-face interviews were conducted by investigators trained in administering the study questionnaires. Investigators used a standardized questionnaire to collect information regarding the participants’ demographic characteristics, current smoking status, current drinking status, physical activity, medical history, and medication use. Social-economic status (SES) has a measurable and significant impact on cardiovascular health. Individuals with low SES carry a substantial burden of CVD and are more likely to experience increased event rates and poorer outcomes [24]. In our study, SES data included information regarding education: no formal education, elementary, middle school, high school or higher, level of education; Occupation: unemployed, laid-off, houseworker, farmer, sales and service staff/worker, private owners, professional skilled worker or administrative and management personnel; Household assets (0~1, 2~3, ≥4); Income (＜10000, 10000 ~ 34999, ≥34999). These variables were used to construct a SES sum score, in accordance with a previous study in China [25]. The score ranges from 0 to 11 points and comprises the domains education, occupation, income and household assets. The exact procedure of the construction is depicted in Supplemental Table 1.

**Statistical analysis**

Data reduction techniques using RRR and PCA were used to derive DPs. Using PCA, a similar number of factors (30 factors) to food groups were produced. However, we retained eleven factors, of which the first two were chosen based on scree plot, eigenvalues (>2) and interpretability. Varimax rotation was applied to attain optimal structure and increase the interpretability of factors. Factor scores for each of the participants and the retained factors were calculated as the sum of the products of factor loading coefficients, which was standardized by the daily intake of each food item. Sample adequacy was checked using the Kaiser-Mayer-Olkin (KMO) test.

In the RRR model, 5 components of MetS (HDL-C, TG, FBG, WC, and MAP) were the dependent variables (Yi) and were used simultaneously in the model, and the 30 food groups (Xi) were the independent variables. The statistical model can be expressed as Yi = α + β× Xi + ε, where ε is the random error. Briefly, RRR extracts linear combinations (the so-called factors or DPs) of predictor variables (e.g., food intakes) that explain as much variation in response variables (e.g., biomarkers of disease), as possible. We used the primary DP for subsequent analyses because it explained the largest amount of variation in MetS components[26]. For the development of DPs, we adjusted blood pressure levels in participants that reported taking any blood pressure lowering drugs by adding a correction constant (systolic blood pressure +15 mmHg; diastolic blood pressure +10 mmHg) [27]. Since there was no adjusted criterion to account for the effect of the medication on FBG [28], we excluded all participants who self-reported using medication for diabetes (n=747) for the RRR analysis. A score for each participant for the primary RRR DP was calculated as the weighted sum of the 30 food groups, with each food group weighted according to its respective factor load value [29].

Finally, we performed multivariate logistic regression analyses to evaluate associations between DPs and MetS and predicted 10-year ASCVD risk, with adjustment for potential confounding variables, such as age, sex, race, living area, SES, smoking status, alcohol consumption (never, occasional, habitual) and physical exercise (never, occasional, habitual). Trends across the quartiles were examined using ordinal variables for DP score and likelihood ratio test. All data analyses were conducted using SAS version 9.4. Statistical significance was defined as a *P* value＜0.05 in 2-sided test.

**Results**

The social-demographic characteristics and lipid profiles of participants by study site are presented in table1. The participants from Urumqi were older than those from Huo Cheng and Mo Yu. Urumqi participants had the highest percentage of highly educated individuals, alcohol drinkers, were most physically active and had the highest metabolic profiles. The highest percentage of current smokers and the highest BMI scores were found in the Huo Cheng participants, whereas the participants had the highest WC. The prevalence of MetS and the predicted 10-year ASCVD risk were significantly higher in Urumqi participants than in those participants from Huo Cheng and Mo Yu.

The main factor loadings of the three retained patterns derived by the three methods are presented in Table 2. A high positive loading indicates a strong direct association between the food group and the pattern, whereas a high negative loading reflects a strong inverse association. The RRR-derived DP for Urumqi was characterized by greater intake of milk tea, and by lower intake of yogurt, gouji berries, red dates, dried vegetables, nuts, eggs, fishes, seafood, whole-grains and soya-bean milk. The major contributors to the first PCA pattern in Urumqi were rice, beef, vegetables, nuts, red dates and gouji berries, all of which were positively correlated with the pattern score. Factor 2 based on the PCA analyses, was characterized by high positive loadings of milk, yogurt, eggs and soya-bean milk. The RRR-derived DP for Huo Cheng participants was characterized by positive loadings of lamb, milk products, milk tea, fruits and nuts, and by negative loadings of beef and fishes/seafood. The first PCA pattern had high positive loadings of beef, beans, pickles, dried vegetable, and had negative loadings of lamb. Factor 2 of the PCA was characterized by high positive loadings of pasta, fruit, potatoes, milk tea, as well as by a negative loading of whole-grains. The RRR-derived DP for Mo Yu was characterized by positive loadings of whole grains, red dates, and by negative loadings of beans, gouji berries, nuts, rice, milk and milk product and pure juice. Factor 1 of the PCA was characterized by high consumption of pasta, lamb, animal innards and pure fruit juice. The second PCA pattern had high positive loadings of eggs, nuts, red dates and raisins. In general, food groups showed lower factor loadings on RRR patterns, resulting in fewer important food groups .

The RRR-derived DP for Urumqi participants explained 1.43% of the variation in the metabolic profile (explained 3.27% of the variation in the MAP and 3.13% of the WC). Using PCA, 25.95% of variation in predictors (30 food groups) was found, compared to 7.42% of RRR. The RRR-derived DP for Huo Cheng participants explained 1.59% of the variation in the metabolic profile (explained 2.12% of the variation in the MAP and 3.41% of the HDL-C) and 8.35% in the predictor variables. The two PCA DPs explaining 25.55% of total variance among 30 food groups. The RRR-derived DP for Mo Yu participants explained 1.08% of the variation in the metabolic profile (explained 2.14% of the variation in the MAP and 2.35% of the WC) and 5.79% in the predictor variables. Using PCA, 22.28% of variation in predictors was found, compared to 5.79% of RRR.

Supplemental Table 2 shows the baseline characteristics of the study population in different study sites by quartiles of DPs. In Urumqi, participants in the highest quartile of the RRR-derived DP were more likely to be older, current smokers, higher SBP, DBP, WC, and have very lower SES. In Huo Cheng, participants in the highest quartile of the RRR-derived DP were more likely to be younger, higher WC and HDL-C. In Mo Yu, participants in the highest quartile of the RRR-derived DP were more likely to be older, higher SBP, DBP, WC, TG, HDL-C, and have very lower SES.

Supplemental Figure S1 presents the association between the number of MetS components and Elevated ASCVD risk in participants in the three sites. As shown in this figure, with increasing in the components of MetS, the risk of ASCVD increases.

The association with MetS for quartiles and per 1SD of the DP score for the three study sites are presented in Table 3. A higher RRR DP score increased the odds for MetS in Urumqi and Mo Yu. In Urumqi, the OR for MetS in the highest quartiles compared to the lowest was 1.57 (95 CI:1.26-1.95), *P* for trend＜0.001 in the fully adjusted model. In Mo Yu, the OR for MetS in the highest quartiles compared to the lowest was 1.23 (95 CI:1.03-1.48), *P* for trend＜0.03 in the fully adjusted model. In the analysis of the correlation between PCA DP and MetS, only the negative correlation between MetS and the first PCA DP in Urumqi was found (OR:0.93; 95% CI:0.86-0.99, *P* for trend=0.157).

The association with predicted 10-year risk of ASCVD for quartiles and per 1 standard deviation (per 1SD) of the DP score for the three study sites are presented in Table 4. In Urumqi, the OR for the elevated 10-year ASCVD risk was 1.55 times higher in the highest quartiles compared with the lowest quartiles of the DP (OR:1.55; 95% CI:1.13-2.13, *P* fortrend=0.001). Per 1SD increase of this DP, the estimated 10-year elevated ASCVD risk increased by 13% (OR:1.30; 95% CI:1.15-1.47) in fully adjusted model1. The DP was not associated with elevated 10-year ASCVD risk in Huo Cheng. In Mo YU, the OR for the elevated 10-year ASCVD risk was 1.63 times higher in the highest quartiles compared with the lowest quartiles of the DP (OR:1.63; 95% CI:1.27-2.08, *P* fortrend＜0.001). Per 1SD increase of this DP, the estimated 10-year elevated ASCVD risk increased by 12% (OR:1.25; 95% CI:1.14-1.36) in fully adjusted model1. The analysis of the association between PCA DP and predicted 10-year risk of ASCVD in different study site also found that only the first PCA DP in Urumqi was a protective factor for ASCVD.

**Discussion**

The high worldwide burden of CVD, and diabetes as the most common cause of mortality and morbidity has led many researchers across the globe to investigate the link between the MetS and diet as a modifiable factor. This survey was conducted in typical multi-ethnic rural areas in China, where the main ethnic groups include Han, Uyghur, Kazakh and Hui. They have special genetic characteristics and lifestyle which are quite different from either the Hans in inland provinces of China or American/European populations [30]. In our study, we found large differences in the eating habits of participants between the three survey sites. Potential influencing factors of MetS include accelerated urbanization and economic growth. As the representative city with the fastest economic development in Xinjiang, Urumqi has a higher MetS prevalence and 10-year ASCVD risk than the other two survey site. This is similar to the previous comparative analysis of MetS prevalence among urban and suburban populations in Beijing[31]. In this study, as the components of the MetS increase, the high-risk ASCVD rate increases. In a relatively large-scale prospective cohort study among the Korean population, an association between MetS, insulin resistance and CVD was found. MetS was associated with risk of CVD, independent of insulin resistance for 10 years of follow-up. Also, the hazard ratio for CVD increased with increasing number of MetS components[32].

We identified and compared DPs using two analysis methods. Using PCA, we derived two DP which characterized the dietary habits of the study population. In Urumqi, the first DP was characterized by high intake of rice, beef, vegetables, nuts, red dates and gouji berries; the second one consisted of high intake of milk, yogurt, eggs and soya-bean milk. Foods composition of these DPs partially overlapped with this “traditional healthy” DP examined by previous study in Xinjiang [33]. The major contributors to the first PCA pattern in Huo Cheng were beef, beans, pickles, dried vegetable, and lamb. The second DP was characterized by high positive loadings of pasta, fruit, potatoes, milk tea, as well as by a negative loading of whole-grains. Similar DPs to those obtained in this study were also identified among Kazakh adults. The DPs of the Kazakh are divided into four types: wheat, rice and dairy (36%); vegetable, dairy and livestock (31.4%); wheat and dairy (25.3%), and wheat-cereal (7.3%)[34]; Based on a cross-sectional study of the diet of adult Uyghur residents in Ka shi, four main DPs of the population in this area were determined. It includes the DP of grain and vegetables; fruits and milk; meat and eggs; dried fruits and nuts[35]. Consistently with results from the Ka shi population, the first Mo Yu DP in this study was characterized by high intake of pasta, lamb, animal innards and pure fruit juice; the second one consisted of high intake of eggs, nuts, red dates and raisins.

In Urumqi, the RRR-derived DP was characterized by greater intake of milk tea, and by lower intake of yogurt, gouji berries, red dates, dried vegetables, nuts, eggs, fishes, seafood, whole-grains and soya milk. The Huo Cheng RRR-derived DP was characterized by positive loadings of lamb, milk products, milk tea, fruits and nuts, and by negative loadings of beef and fishes/seafood. The RRR-derived DP for Mo Yu was characterized by positive loadings of whole grains, red dates, and by negative loadings of beans, gouji berries, nuts, rice, milk and milk product and pure juice.

Obviously, the DPs extracted by the two methods in this study are different. We found that even though the explained biomarker variation was low, RRR-derived DP were more strongly associated with diseases than PCA-derived patterns. PCA does not necessarily explain the variation and amount of nutrient intake in the identified patterns, rather it explains the cultural and behavioral aspects of food [36]. In line with this, our results showed that although PCA explains the highest variation in food groups, only the first DP derived from PCA in Urumqi was significantly associated with MetS and ASCVD.

Although the DPs derived from a RRR depend on the biomarkers and data included, the food groups that characterized the DP identified in this study have also been reported previously to exert protective effects against MetS and ASCVD. For example, Some scholars derived DPs using the RRR method with MetS as the intermediate variables and found a DP characterized by several foods including those with high glycemic indices, high-fat meats, cheeses, and processed foods, and negatively correlated with intakes of vegetables, soy, fruit, green and black tea, low-fat dairy desserts, seeds, nuts, and fish[37]. A recent study using data from the China Health and Nutrition Survey reported that the primary RRR dietary score were positively correlated with intakes of wheat or its products, but negatively correlated with low intakes of rice or its products, dark vegetables and animal oil for both genders[38].

Results of this study support the current dietary guidelines (Dietary Guidelines for Chinese, DGC-2016), suggesting, for example, increasing the consumption of dairy and nuts[39]. A cross-sectional study, conducted among 130,420 subjects concluded that higher milk consumption was associated with the lower odds of MetS in Korean adults[40]. Prospective cohort studies consistently suggest that yogurt consumption may contribute to a reduction in adiposity indexes, the risk of MetS and diet-related cardiometabolic diseases[41-42]. Our study in Urumqi showed that yogurt had the highest impact on the metabolic profile associated DPs. However, it may be due to the shortage of cow resources, which leads to the low consumption of milk and dairy products in Mo Yu. Besides yogurt, milk tea is the second popular dairy product in Xinjiang. So, it is worth noting the relationship between milk tea and the risk of MetS and predicted ASCVD. Hydrogenated vegetables oils used in the processing of dairy products such as milk tea also contain a large amount of trans fatty acids[43]. The high intake of trans fatty acids promotes arteriosclerosis, causes type 2 diabetes, and heart disease[44].

Epidemiologists found a negative correlation between the frequency of nut consumption and the incidence of MetS[45], and the beneficial effects of nuts on cardiovascular health are attributed to their abundance of a variety of bioactive compounds. Another study have shown that people with higher whole-grain intake have a 29% lower ASCVD risk than those with lower whole-grain intake[46]. However, the opposite result was found between whole grains and the risk of MetS and elevated ASCVD in Mo Yu. Mo Yu is one of the poorest areas in Xinjiang and people have low SES. Increasing whole-grains cereals only, may not influence adiponectin levels, but levels could be modified by a fiber rich, low-fat, low-glycemic index diet, possibly through changes in gut microbiota[47]. A study examined anthropometric and biochemical parameters in patients with MetS after the consumption of gouji berries and results suggested that it is an effective dietary supplement for the prevention of cardiovascular diseases in individuals with MetS[48]. Our results are also in agreement with a study that found that lower consumption of gouji berries and eggs may increase the risk of MetS and elevated ASCVD[49]. Studies on the relationship between eggs intake and MetS and ASCVD are inconsistent. A previous study has suggested that incorporating daily eggs intake into a moderately carbohydrate-restricted diet provides further improvements in the atherogenic lipoprotein profile and in insulin resistance in individuals with MetS[50].

Strengths and limitations

To the best of our knowledge, this study is the first to investigate potential relationships between overall diet and metabolic profiles in Xinjiang. We are aware that the RRR method is limited to existing studies with biomarkers or intermediate variables and knowledge of the diet-disease association. Nevertheless, this innovative method has the advantage of investigating the pathway between diet and disease, as opposed to exploratory factor analysis and cluster analysis which are entirely data driven. The strength of our study included the large sample size and the fact that we included three survey sites with different geographical, cultural and socioeconomic characteristics. We focused on central obesity rather than BMI. The reasons are as follows. Firstly, according to the IDF definition, central obesity is the first step to defining MetS, followed by the other IDF factors. Additionally, it was associated with insulin resistance and contributed to MetS and its components. Moreover, significant evidence linked larger waist circumferences with the development of CVD[51]. Most importantly, the prevalence of adult central obesity in Xinjiang is significantly higher than that in other regions[17].

We acknowledge that our study has some limitations. Firstly, we acknowledge that the retrospective FFQ bears the risk of under-or over-reporting of food items in the dietary assessments. The administration of a locally specific FFQ, by trained nurses of the same cultural background and language helped to keep this information bias to a minimum. Second, our cross-sectional analyses may be affected by reverse causation due to changes in dietary behavior as a result of developing MetS. Third, residual confounding, particularly from physical activities that are hard to measure precisely with a self-report questionnaire and that are closely related to both MetS and diet in terms of energy intake and type of DP. Furthermore, since the FFQ used in our study only investigated food group intake without reporting single foods, it is impossible to accurately calculate the individual's daily energy intake. Finally, because information regarding hyperlipidemia medication was not available, HDL-C and TG were not adjusted in those participants taking lipid-lowering medication. Further studies are needed to explore the association of DPs with MetS and ASCVD 10-year risk using a longitudinal study.

**Conclusion**

We derived DPs that reflected metabolic profiles using RRR and PCA analyses. These DPs were associated with higher risk of MetS and elevated 10-year ASCVD risk in Chinese adults. Our findings suggest that using metabolic profile biomarkers as response variables in RRR may be a promising approach to identify DPs related to chronic disease risk. Furthermore, our findings may help clinicians and dietitian develop dietary strategies for preventing MetS and ASCVD.

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**Authorship**

GH, DL-W and JH-D designed the research; GH, ZC, TT, TL, DA: contributed to the analysis and interpretation of data for the work; GH, WH-F and LW : wrote the paper; TL, JH-D: contributed to acquisition of the data; and all authors provided input and approved the final manuscript.

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**Conflict of Interest :** None of the authors has any conflicts of interest to declare.

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**Table 1 Distribution of socio-demographic and cardiovascular disease risk factors by site**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Variables |  | Urumqi(n=4265) | Huo Cheng(n=3467) | Mo Yu (n=7250) |  | *P*-value |
| Age, year |  | 59.88±9.43 | 50.16±9.77 | 52.19±10.26 | 1129.97 | ＜0.001 |
| Gender, n (females，%) |  | 2635 (61.8) | 1845 (53.2) | 4404 (60.7) | 70.33 | ＜0.001 |
| Ethnic group, n (%) | Han | 3732 (87.5) | 457 (10.9) | 6 (0.1) | 7470.10 | ＜0.001 |
|  | Uyghur | 108 (2.5) | 1028 (29.7) | 7217 (99.5) |  |  |
|  | Hui | 360 (8.4) | 1067 (30.8) | 12 (0.2) |  |  |
|  | Kazakh | 28 (0.7) | 912 (26.3) | 15 (0.2) |  |  |
|  | other | 37 (0.2) | 3 (0.1) | 0 (0.0) |  |  |
| Education, n (%) | No formal education | 464 (10.9) | 814 (23.5) | 1181 (16.3) | 4145.90 | ＜0.001 |
|  | elementary | 1088 (25.5) | 1639 (47.3) | 5243 (72.3) |  |  |
|  | middle school | 1496 (35.1) | 771 (22.2) | 736 (10.2) |  |  |
|  | high school or higher | 1217 (28.5) | 243 (7.0) | 90 (1.2) |  |  |
| Physical activity, n (%) | never | 1734 (40.7) | 2794 (80.6) | 6942 (95.8) | 5320.17 | ＜0.001 |
|  | occasional | 813 (19.1) | 509 (14.7) | 178 (2.5) |  |  |
|  | habitual | 1718 (40.2) | 154 (4.7) | 130 (1.7) |  |  |
| SES, n (very low，%) |  | 716 (16.8) | 1877 (54.1) | 4428 (51.1) | 4213.77 | ＜0.001 |
| Current smoking status, n (%) |  | 616 (14.4) | 861 (24.8) | 637 (8.8) | 498.95 | ＜0.001 |
| Alcohol drinking status, n (%) | never | 3331 (781) | 2870 (82.8) | 5835 (94.3) | 909.30 | ＜0.001 |
|  | occasional | 726 (17.0) | 550 (15.9) | 187 (2.6) |  |  |
|  | habitual | 208 (4.9) | 47 (1.4) | 228 (3.1) |  |  |
| Weight (kg) |  | 66.96±11.31 | 68.42±12.61 | 61.95±12.42 | 418.40 | ＜0.001 |
| Height (cm) |  | 161.89±8.26 | 161.29±9.00 | 157.06±8.44 | 540.90 | ＜0.001 |
| WC (cm) |  | 88.77±9.87 | 89.33±11.43 | 91.48±11.64 | 93.57 | ＜0.001 |
| SBP (mmHg) |  | 128.83±17.79 | 126.18±20.46 | 119.75±20.15 | 321.49 | ＜0.001 |
| DBP (mmHg) |  | 77.38±10.42 | 74.54±10.71 | 72.94±12.19 | 204.60 | ＜0.001 |
| TC (mmol/L) |  | 4.98±1.50 | 4.92±1.30 | 4.55±2.18 | 95.71 | ＜0.001 |
| HDL-C (mmol/L) |  | 1.51±0.52 | 1.33±0.76 | 1.34±0.53 | 136.19 | ＜0.001 |
| TG (mmol/L) |  | 1.78±1.30 | 1.46±0.98 | 1.37±1.45 | 135.25 | ＜0.001 |
| FBG (mmol/L) |  | 5.89±1.80 | 5.48±1.24 | 5.21±1.09 | 335.44 | ＜0.001 |
| MetS, n (%) |  | 1134 (26.6) | 728 (21.0) | 1631 (22.5) | 38.69 | ＜0.001 |
| MetS components | 1 | 1151 (27.0) | 1138 (32.8) | 2475 (34.1) | 192.38 | ＜0.001 |
|  | 2 | 1463 (34.3) | 1045 (30.1) | 2462 (34.0) |  |  |
|  | 3 | 823 (19.3) | 572 (16.5) | 1180 (16.3) |  |  |
|  | 4 | 286 (6.7) | 139 (4.0) | 390 (5.4) |  |  |
|  | 5 | 25 (0.6) | 17 (0.5) | 61 (0.8) |  |  |
| ASCVD risk, n (%) | ＜5% | 1803 (42.3) | 2192 (63.2) | 4839 (66.7) | 725.33 | ＜0.001 |
|  | 5%-10% | 1467 (34.4) | 654 (18.9) | 1438 (19.8) |  |  |
|  | ≥10 | 995 (23.2) | 621 (17.9) | 973 (13.4) |  |  |

SES, social economic status; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglyceride; TC, total cholesterol; HDL-C, high density lipoprotein; LDL-C, low density lipoprotein; MetS, metabolic syndrome; ASCVD, atherosclerotic cardiovascular disease.

**Table 2 Factor loadings of food groups in DPs identified using reduced-rank regression and principle component analysis**

|  |  |  |  |
| --- | --- | --- | --- |
| Food groups | Urumqi (n=4265) | Huo Cheng (n=3467) | Mo Yu (n=7250) |
|  | RRR | PCA1 | PCA2 | RRR | PCA1 | PCA2 | RRR | PCA1 | PCA2 |
| Rice | -0.19  | - | - | - | - | - | -0.26  | - | - |
| Pasta | -  | - | - | -  | - | 0.51 | -  | - | 0.13 |
| Grains | -0.22  | 0.30 | 0.25 | 0.20  | - | -0.42 | 0.27  | - | - |
| Pork | -0.20  | -0.15 | - | -0.15  | - | -0.23 | - | - | - |
| Lamb | -  | 0.14 | 0.21 | 0.49  | -0.49 | 0.28 | -0.18  | - | 0.11 |
| Beef | 0.13  | 0.14 | - | -0.28  | 0.65 | - | -0.14  | - | 0.11 |
| Poultry | -0.17  | 0.13 | 0.15 | -  | 0.16 | 0.18 | -  | 0.14 | -0.17 |
| Seafood | -0.24  | 0.23 | 0.11 | -0.17  | 0.19 | - | -0.11  | 0.11 | - |
| Eggs | -0.24  | 0.17 | 0.55 | 0.12  | - | - | 0.11  | - | 0.63 |
| Animal innards | -  | - | -0.25 | 0.16  | - | - | -0.10  | - | - |
| Vegetables | -  | - | - | -0.10  | - | 0.34 | 0.15  | - | 0.17 |
|  Fruits | -0.20  | 0.13 | 0.13 | 0.27  | -0.14 | 0.53 | -  | - | - |
| Potatoes | -  | 0.22 | 0.20 | -  | - | 0.68 | -0.13  | 0.11 | 0.23 |
| Beans | -  | 0.17 | 0.33 | -  | 0.46 | - | -0.37  | 0.29 | -0.28 |
| Milk | -0.10  | - | 0.72 | 0.21  | - | 0.19 | -0.23  | 0.14 | - |
| Yogurt | -0.31  | 0.26 | 0.65 | 0.11  | 0.12 | - | - | - | 0.12 |
| Other dairy products | -  | - | - | 0.36  | -0.25 | 0.34 | -0.25  | 0.15 | -0.23 |
| Shortening tea | 0.14  | - | - | -  | - | - | -  | - | - |
| Milk tea | 0.30  | - | 0.13 | 0.33  | -0.35 | 0.35 | -0.14  | - | - |
| Pickles | -  | 0.11 | - | -0.14  | 0.69 | - | -0.20  | 0.14 | - |
| Dried vegetable | -0.21  | 0.40 | 0.20 | -  | 0.69 | 0.17 | -  | -0.15 | 0.34 |
| Nuts | -0.26  | 0.77 | 0.15 | 0.23  | - | 0.18 | 0.24  | -0.14 | 0.74 |
| Red dates | -0.26  | 0.81 | 0.17 | 0.11  | - | - | 0.25  | 0.14 | 0.58 |
| Gouji berries | -0.29  | 0.81 | 0.13 | -  | 0.21 | - | -0.34  | 0.66 | - |
| Raisins | -0.25  | 0.84 | - | 0.12  | - | - | -  | - | 0.66 |
| Dried apricots | -0.25  | 0.77 | - | 0.14  | - | - | -0.27  | 0.66 | 0.20 |
| Soya-bean milk | -0.21  | 0.21 | 0.46 | -  | 0.11 | - | -0.19  | 0.69 | - |
| Pure fruit juice | -  | 0.18 | 0.22 | -  | 0.18 | 0.11 | -0.22  | 0.80 | - |
| Carbonated drinks | -  | - | - | 0.12  | - | - | -0.13  | 0.31 | - |
| Other drinks | - | - | - | - | - | - | -  | - | 0.16 |

Loadings lower than │0.1│ were deleted for simplicity.

**Table 3 Odds ratios (OR) and 95% confidence intervals of observing MetS by quartiles and per 1SD of the DP score**

|  |  |  |  |
| --- | --- | --- | --- |
| Food groups | Urumqi (n=4265) | Huo Cheng (n=3467) | Mo Yu (n=7250) |
|  | Crude model | Adjusted model | Crude model | Adjusted model | Crude model | Adjusted model |
| RRR |  |  |  |  |  |  |
| Q1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Q2 | 1.33(1.09-1.63) | 1.30(1.05-1.60) |  0.79(0.64-0.99) | 0.873(0.69-1.11) | 1.13(0.97-1.32) | 1.09(0.93-1.28) |
| Q3 | 1.48(1.22-1.81) | 1.39(1.13-1.71) |  0.73(0.58-0.91) | 0.99(0.75-1.30) | 1.13(0.97-1.32) | 1.09(0.92-1.29) |
| Q4 | 1.83(1.51-2.23) | 1.57(1.26-1.95) | 0.58(0.05-0.73) | 0.89(0.61-1.28) | 1.17(1.00-1.37) | 1.23(1.03-1.48) |
| *P*-trend | ＜0.001 | ＜0.001 | ＜0.001 | 0.663 | 0.069 | 0.040 |
| DP (per1SD increase) | 1.24(1.16-1.33) | 1.17(1.08-1.27) | 0.81(0.74-0.88) | 0.93(0.81-1.07) | 1.08(1.03-1.14) | 1.11(1.04-1.19) |
| PCA1 |  |  |  |  |  |  |
| Q1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Q2 | 1.00(0.825-1.21) | 0.94(0.77-1.14) | 0.99(0.78-1.26) | 0.87(0.68=1.12) | 1.19(1.02-1.39) | 1.15(0.99-1.35) |
| Q3 | 0.96(0.79-1.16) | 0.92(0.76-1.12) | 1.17(0.92-1.47) | 0.93(0.71-1.21) | 1.11(0.95-1.30) | 1.13(0.96-1.32) |
| Q4 | 0.85(0.70-1.03) | 0.80(0.65-0.97) | 1.23(0.98-1.56) | 1.00(0.76-1.34) | 1.07(0.91-1.25) | 1.12(0.95-1.31) |
| *P*-trend | 0.305 | 0.157 | 0.161 | 0.612 | 0.180 | 0.290 |
| DP (per 1SD increase) | 0.94(0.88-1.00) | 0.93(0.86-0.99) | 1.08(0.99-1.17) | 0.99(0.90-1.10) | 1.01(0.96-1.07) | 1.04(0.98-1.09) |
| PCA2 |  |  |  |  |  |  |
| Q1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Q2 | 1.04(0.86-1.25) | 1.04(0.86-1.26) | 1.20(0.91-1.58) | 1.15(0.86-1.52) | 1.03(0.88-1.20) | 1.04(0.90-1.22) |
| Q3 | 0.93(0.75-1.16) | 0.92(0.74-1.15) | 1.06(0.84-1.34) | 1.13(0.88-1.44) | 1.05(0.89-1.25) | 1.05(0.88-1.25) |
| Q4 | 1.01(0.84-1.21) | 1.008(0.82-1.22) | 0.90(0.72-1.13) | 1.10(0.86-1.40) | 0.97(0.85-1.11) | 0.98(0.86-1.13) |
| *P*-trend | 0.806 | 0.72 | 0.124 | 0.750 | 0.810 | 0.834 |
| DP (per 1SD increase) | 0.99(0.93-1.06) | 0.99(0.92-1.06) | 0.93(0.85-1.00) | 0.99(0.91-1.08) | 0.99(0.94-1.05) | 0.99(0.94-1.05) |

\*Urumqi adjusted model: adjusted for age, sex, race (han, other), very lower SES (no, yes), current smoking status (no, yes), alcohol drinking status (never, occasional, habitual), physical exercise (never, occasional, habitual) and living area;

Huo Cheng adjusted model: adjusted for age, sex, race (Han, Uyghur, Hui, Kazakh), very lower SES (no, yes), current smoking status (no, yes), alcohol drinking status (never, occasional, habitual), physical exercise (never, occasional, habitual) and living area;

Mo Yu adjusted model: adjusted for age, sex, very lower SES (no, yes), current smoking status (no, yes), alcohol drinking status (never, occasional, habitual), physical exercise (no, yes) and living area.

**Table 4 Odds ratios (OR) and 95% confidence intervals of predicting 10-year ASCVD risk by quartiles and per 1 SD of the DP score**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Urumqi (n=4265) | Huo Cheng(n=3467) | Mo Yu (n=7250) |
|  | Crude model | Adjusted model | Crude model | Adjusted model | Crude model | Adjusted model |
| RRR |  |  |  |  |  |  |
| Q1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Q2 | 1.58(1.33-1.87) | 1.53(1.14-2.05) | 0.92(0.75-1.13) | 0.99(0.74-1.33) | 1.11(0.96-1.29) | 1.17(0.93-1.46) |
| Q3 | 2.44(2.05-2.90) | 2.22(1.64-3.00) | 0.68(0.55-0.84) | 0.92(0.65-1.30) | 1.54(1.34-1.78) | 1.34(1.07-1.68) |
| Q4 | 3.46(2.89-4.14) | 1.55(1.13-2.13) | 0.50(0.40-0.62) | 0.79(0.50-1.23) | 2.43(2.11-2.80) | 1.63(1.27-2.08) |
| *P*-trend | ＜0.001 | 0.005 | ＜0.001 | 0.340 | ＜0.001 | ＜0.001 |
| DP (per1SD increase) | 1.69(1.58-1.81) | 1.30(1.15-1.47) | 0.74(0.69-0.80) | 0.87(0.73-1.03) | 1.411(1.34-1.49) | 1.25(1.14-1.36) |
| PCA1 |  |  |  |  |  |  |
| Q1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Q2 | 1.23(1.03-1.46) | 0.71(0.53-0.96) | 1.28(1.06-1.56) | 1.17(0.87-1.58) | 1.221.06-1.39) | 0.91(0.74-1.13) |
| Q3 | 0.99(0.83-1.17) | 0.77(0.57-1.03) | 1.38(1.13-1.67) | 1.30(0.95-1.79) | 0.89(0.78-1.03) | 1.05(0.85-1.29) |
| Q4 | 0.83(0.70-0.98) | 0.57(0.42-0.76) | 1.07(0.88-1.31) | 0.95(0.68-1.34) | 0.70(0.61-0.81) | 1.02(0.82-1.27) |
| *P*-trend | ＜0.001 | 0.003 | 0.004 | 0.116 | ＜0.001 | 0.605 |
| DP (per 1SD increase) | 0.92(0.86-0.97) | 0.83(0.75-0.93) | 1.06(0.99-1.14) | 1.03(0.92-1.17) | 0.861(0.83-0.91) | 1.02(0.95-1.10) |
| PCA2 |  |  |  |  |  |  |
| Q1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Q2 | 1.10(0.93-1.30) | 1.32(1.00-1.7) | 1.03(0.82-1.30) | 0.87(0.62-1.23) | 0.09(0.78-1.02) | 0.85(0.69-1.05) |
| Q3 | 0.93(0.77-1.13) | 0.85(0.62-1.16) | 0.79(0.64-0.96) | 0.80(0.60-1.07) | 0.959(0.823-1.12) | 0.87(0.69-1.10) |
| Q4 | 0.87(0.74-1.02) | 0.77(0.59-1.03) | 0.68(0.57-0.82) | 0.94(0.71-1.25) | 0.76(0.67-0.85) | 0.88(0.73-1.06) |
| *P*-trend | 0.031 | 0.002 | ＜0.001 | 0.454 | ＜0.001 | 0.36 |
| DP (per 1SD increase) | 0.93(0.88-0.99) | 0.87(0.79-0.97) | 0.86(0.81-0.92) | 0.97(0.88-1.08) | 0.90(0.86-0.94) | 0.95(0.88-1.03) |

\*Urumqi adjusted model: adjusted for age, sex, race (han, other), very lower SES (no, yes), current smoking status (no, yes), alcohol drinking status (never, occasional, habitual), physical exercise (never, occasional, habitual) and living area;

Huo Cheng adjusted model: adjusted for age, sex, race (Han, Uyghur, Hui, Kazakh), very lower SES (no, yes), current smoking (no, yes), alcohol drinking (never, occasional, habitual), physical exercise (never, occasional, habitual) and living area;

Mo Yu adjusted model: adjusted for age, sex, very lower SES (no, yes), current smoking (no, yes), alcohol drinking (never, occasional, habitual), physical exercise (no, yes) and living area.

**Supplement**

Table S1. SES evaluation of each variable assignment criteria

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Occupation | Education | Annual income（Yuan） | Household assets | score |
| unemployed / laid-off / housework | never | ＜10000 | 0~1 | 0 |
| farmer | elementary | 10000~34999 | 2~3 | 1 |
| sales and service staff / workers / other | middle school | ≥34999 | ≥4 | 2 |
| private owners | high school or higher |  |  | 3 |
| professional skill worker / administrative and management personnel |  |  |  | 4 |

**Table S2 Characteristics and biomarkers by quartiles of DP score in participants from the three study sites**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Quartile of the DP score ( Urunqi) | Quartile of the DP score ( Huo Cheng) | Quartile of the DP score ( Mo Yu) |
|  | 1 | 2 | 3 | 4 | *P*-for trend | 1 | 2 | 3 | 4 | *P*-for trend | 1 | 2 | 3 | 4 | *P*-for trend |
| RRR |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Age (years) | 58.00 ±9.41 | 58.85 ± 9.67 | 60.33 ± 9.64 | 62.33 ± 8.39 | ＜0.001 | 51.57±10.06 | 50.55 ± 9.86 | 49.02 ± 9.65 | 49.49 ± 9.31 | ＜0.001 | 50.23±9.79 | 50.44 ± 9.99 | 52.48 ± 10.15 | 55.63 ± 10.18 | ＜0.001 |
| Sex (female) | 776 (72.4) | 654 (62.2) | 639 (59.4) | 566 (53.0) | ＜0.001 | 445 (51.6) | 399 (45.7) | 464 (53.8) | 537 (51.8) | ＜0.001 | 1083 (60.0) | 1133 (62.0) | 1104 (61.1) | 1084 (59.8) | 0.510 |
| Current smoking status, n (%) | 114 (10.6) | 146 (13.9) | 159 (14.8) | 197 (18.5) | ＜0.001 | 157 (18.2) | 237 (27.1) | 238 (27.6) | 229 (26.4) | ＜0.001 | 189 (10.5) | 154 (8.4) | 154 (8.5) | 140 (7.7) | 0.027 |
| Alcohol drinking status, n (%) | 49 (4.6) | 50 (4.8) | 45 (4.2) | 64 (6.0) | 0.437 | 110 (12.7) | 149 (17.1) | 142 (16.5) | 149 (17.1) | 0.015 | 47 (2.6) | 49 (2.7) | 76 (4.2) | 56 (3.1) | 0.049 |
| Physical activity, n (%) | 555 (51.8) | 417 (39.7) | 358 (33.3) | 380 (35.6) | ＜0.001 | 43 (5.0) | 23 (2.6) | 43 (5.0) | 40 (4.6) | 0.001 | 27 (1.5) | 15 (0.8) | 14 (0.8) | 29 (1.6) | 0.026 |
| Very low SES, n (%) | 56 (5.2) | 120 (11.4) | 209 (19.4) | 331 (31.0) | ＜0.001 | 488 (56.5) | 458 (52.5) | 481 (55.8) | 450 (51.8) | 0.116 | 978 (54.2) | 1056 (57.8) | 1180 (65.3) | 1214 (67.0) | ＜0.001 |
| SBP (mmHg) | 126.03 ±18.04 | 129.13 ±17.95 | 131.86 ± 18.89 | 133.38 ± 19.17 | ＜0.001 | 132.20±24.01 | 128.55±22.55 | 125.36±22.40 | 125.03 ± 20.99 | ＜0.001 | 119.63 ±21.49 | 121.07 ± 22.48 | 122.38 ± 22.79 | 126.16 ±25.12 | ＜0.001 |
| DBP (mmHg) | 75.41 ± 10.35 | 77.99 ± 10.82 | 78.95 ± 10.98 | 80.54 ± 11.36 | ＜0.001 | 77.39 ± 12.07 | 76.47 ± 10.66 | 75.14 ± 11.04 | 73.46 ± 11.58 | ＜0.001 | 72.71 ± 13.02 | 73.71 ± 13.24 | 74.91 ± 13.34 | 77.25 ± 13.84 | ＜0.001 |
| WC (cm) | 86.43 ± 9.39 | 88.85 ± 9.68 | 89.18 ± 9.75 | 90.65 ± 10.21 | ＜0.001 | 87.95 ± 10.29 | 87.99 ± 11.11 | 89.45 ± 11.97 | 91.93 ± 11.84 | ＜0.001 | 89.15 ± 11.60 | 90.88 ± 11.51 | 91.68 ± 11.48 | 94.20 ± 11.41 | ＜0.001 |
| FBG (mmol/L) | 5.80 ± 1.62 | 5.87 ± 1.71 | 5.95 ± 1.97 | 5.93 ± 1.89 | 0.049 | 5.50 ± 1.21 | 5.36 ± 1.09 | 5.46 ± 1.36 | 5.60 ± 1.29 | 0.43 | 5.14 ± 1.01 | 5.23 ± 1.08 | 5.23 ± 1.11 | 5.22 ± 1.16 | 0.030 |
| TG (mmol/L) | 1.87 ± 0.43 | 1.78 ± 0.45 | 1.73 ± 0.14 | 1.76 ± 0.78 | 0.043 | 1.58 ± 0.14 | 1.46 ± 0.98 | 1.38 ± 0.94 | 1.41 ± 0.83 | ＜0.001 | 1.23 ± 0.95 | 1.33 ± 0.97 | 1.42 ± 0.15 | 1.51 ±0.29 | ＜0.001 |
| HDL-C (mmol/L) | 1.56 ± 0.59 | 1.51 ± 0.50 | 1.51 ± 0.50 | 1.46 ± 0.48 | ＜0.001 | 1.24 ± 0.77 | 1.21 ± 0.69 | 1.28 ± 0.92 | 1.60 ± 0.53 | ＜0.001 | 1.30 ± 0.48 | 1.31 ± 0.64 | 1.35 ± 0.50 | 1.39 ± 0.48 | ＜0.001 |
| PCA DP1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Age (years) |  58.93± 9.75  | 60.89± 9.48 | 59.86± 9.45 | 59.88± 9.43 | 0.205 | 50.19± 9.72 | 50.75± 9.95 | 50.50± 9.84 | 49.35± 9.54 | 0.081 | 52.55 ± 10.19 | 54.28 ± 10.73 | 51.88 ± 10.03 | 50.06 ± 9.62 | ＜0.001 |
| Sex (female) | 616（23.4） | 635（24.1） | 667（25.3） | 717（27.2） | ＜0.001 | 505(27.4) | 461(25.0) | 431(23.4) | 448(24.3) | 0.002 | 1084(24.6) | 1098(24.9) | 1189(27.0) | 1033(23.5) | 0.574 |
| Current smoking status, n (%) | 182（29.5） | 174（28.2） | 133（21.6） | 127（20.6） | ＜0.001 | 249(28.9) | 240(27.9) | 199(23.1) | 173(20.1) | ＜0.001 | 172(27.0) | 146(22.9) | 120(18.8) | 199(31.2) | 0.296 |
| Alcohol drinking status, n (%) | 207（22.2） | 273（29.2） | 216（23.1） | 238（25.5） | 0.623 | 174(29.1) | 153(25.6) | 151(25.3) | 119(19.9) | 0.005 | 128(30.8) | 113(27.2) | 70(16.9) | 104(25.1) | 0.010 |
| Physical activity, n (%) | 571（22.6） | 613（24.2） | 635（25.1） | 712（28.1） | ＜0.001 | 174(25.9) | 171(25.4) | 172(25.6) | 156(23.2) | 0.684 | 83(26.9) | 62(20.1) | 70(22.7) | 93(30.2) | 0.314 |
| Very low SES, n (%) | 168（23.5） | 235（32.8） | 177（24.7） | 136（19.0） | 0.004 | 488(26.0) | 464(24.7) | 436(23.2) | 489(26.1) | 0.019 | 1140(25.7) | 1200(27.1) | 1111(25.1) | 977(22.1) | ＜0.001 |
| SBP (mmHg) | 129.63± 17.84 | 131.98± 19.51 | 130.33± 18.18 | 128.47± 18.18 | 0.046 | 126.02± 21.15 | 128.20± 23.33 | 129.41±23.47 | 127.48± 22.60 | 0.106 | 121.88± 22.91 | 123.35 ± 23.81 | 122.69 ± 23.41 | 121.33± 22.34 | 0.344 |
| DBP (mmHg) | 78.27± 10.63 | 79.24± 11.20 | 78.51± 11.10 | 76.88± 11.10 | 0.001 | 74.41± 11.37 | 75.53± 11.39 | 75.92± 11.62 | 76.59± 11.29 | ＜0.001 | 75.37 ± 13.13 | 76.00 ± 13.49 | 74.12 ± 13.60 | 73.11 ± 13.47 | ＜0.001 |
| WC (cm) | 89.36± 9.42 | 89.25± 9.90 | 88.8± 9.821 | 87.69± 10.26 | ＜0.001 | 90.78± 11.76 | 89.07± 11.52 | 89.22± 11.03 | 88.27± 11.28 | ＜0.001 | 93.28 ± 11.33 | 93.06 ± 11.47 | 89.83 ± 11.89 | 89.74 ± 11.38 | ＜0.001 |
| FBG (mmol/L) | 5.94± 1.72 | 5.99± 1.96 | 5.89± 1.85 | 5.73± 1.66 | 0.004 | 5.48± 1.15 | 5.49± 1.30 | 5.49± 1.21 | 5.48± 1.24 | 0.729 | 5.20 ± 1.10 | 5.25 ± 1.14 | 5.21 ± 0.99 | 5.17 ± 1.12 | 0.244 |
| TG (mmol/L) | 1.70± 0.12 | 1.77± 0.29 | 1.82± 0.29 | 1.85± 1.48 | 0.005 | 1.36± 0.80 | 1.44± 0.94 | 1.52± 0.12 | 1.51± 0.03 | ＜0.001 | 1.44 ± 0.28 | 1.49 ± 0.15 | 1.28 ± 0.93 | 1.29 ± 0.10 | ＜0.001 |
| HDL-C (mmol/L) | 1.49± 0.49 | 1.51± 0.53 | 1.52± 0.49 | 1.52± 0.56 | 0.005 | 1.47± 0.63 | 1.33± 0.74 | 1.29±0.68 | 1.23± 0.92 | ＜0.001 | 1.35 ± 0.45 | 1.38 ± 0.52 | 1.30± 0.53 | 1.31 ± 0.60 | ＜0.001 |
| PCA DP2 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Age (years) | 59.67± 9.40 | 59.97± 9.40 | 60.13± 9.21 | 59.83± 9.63 | 0.597 | 51.10±9.75 | 52.12±10.09 | 50.17±9.82 | 48.90±9.45 | ＜0.001 | 52.89 ± 10.36 | 52.25 ± 10.43 | 52.81 ± 10.35 | 51.19 ± 9.94 | ＜0.001 |
| Sex (female) | 616（23.4） | 747（28.3） | 459（17.4） | 813（30.9） | ＜0.001 | 371(20.1) | 259(14.0) | 514(27.9) | 701(38.0) | 0.844 | 1526(34.7) | 860(19.5) | 618(14.0) | 1400(31.8) | 0.008 |
| Current smoking status, n (%) | 182（29.5） | 182（29.5） | 100（16.2） | 152（24.7） | 0.002 | 189(22.0) | 104(12.1) | 228(26.5) | 340(39.5) | 0.525 | 173(27.2) | 117(18.4) | 96(15.1) | 251(39.4) | ＜0.001 |
| Alcohol drinking status, n (%) | 223（23.9） | 261（27.9） | 166（17.8） | 284（30.4） | 0.102 | 138(23.1) | 77(12.9) | 159(26.6) | 223(37.4) | 0.390 | 107(25.8) | 55(13.3) | 62(14.9) | 191(46.0) | ＜0.001 |
| Physical activity, n (%) | 598（23.6） | 652（25.8） | 458（18.1） | 823（32.5） | ＜0.001 | 120(17.8) | 78(11.6) | 180(26.7) | 295(43.8) | 0.001 | 108(35.1) | 50(16.2) | 31(10.1) | 119(38.6) | 0.379 |
| Very low SES, n (%) | 214（29.9） | 253（35.3） | 108（15.1） | 141（19.7） | ＜0.001 | 366(19.5) | 259(13.8) | 536(28.6) | 716(38.1) | 0.297 | 1631(36.8) | 878(19.8) | 638(14.4) | 1281(28.9) | ＜0.001 |
| SBP (mmHg) | 130.97± 19.24 | 130.55± 18.41 | 130.27± 19.00 | 128.80± 18.38 | 0.006 | 130.87±23.34 | 130.73±23.58 | 127.24±22.21 | 125.39±22.03 | ＜0.001 | 123.88± 23.61 | 123.02 ± 23.61 | 122.10 ± 22.23 | 120.37± 22.23 | ＜0.001 |
| DBP (mmHg) | 79.61± 11.29 | 78.63± 11.21 | 77.73± 10.57 | 76.88± 10.74 | ＜0.001 | 76.38±11.83 | 76.08±11.79 | 76.21±11.13 | 74.58±11.25 | 0.002 | 74.39 ± 13.78 | 74.42 ± 13.74 | 74.35 ± 13.49 | 75.18 ± 12.95 | 0.074 |
| WC (cm) | 89.19± 10.27 | 88.98± 9.91 | 88.12± 9.56 | 88.19± 9.64 | 0.016 | 89.16±10.65 | 89.72±11.62 | 88.87±11.04 | 89.63±12.04 | 0.753 | 90.91 ± 11.80 | 90.01 ± 11.88 | 91.15 ± 11.38 | 93.07 ± 11.26 | ＜0.001 |
| FBG (mmol/L) | 5.59± 1.28 | 5.75± 1.49 | 5.83± 1.69 | 6.31± 2.38 | ＜0.001 | 5.49±1.09 | 5.12±1.22 | 5.47±1.34 | 5.47±1.25 | 0.488 | 5.22 ± 1.03 | 5.20 ± 1.14 | 5.23 ± 1.05 | 5.19 ± 1.14 | 0.498 |
| TG (mmol/L) | 1.86± 0.43 | 1.78± 0.30 | 1.76± 0.21 | 1.73± 0.24 | 0.024 | 1.50±0.92 | 1.50±0.88 | 1.49±0.14 | 1.39±0.92 | 0.025 | 1.33±0.07 | 1.27±0.97 | 1.45±0.88 | 1.45±0.08 | ＜0.001 |
| HDL-C (mmol/L) | 1.51± 0.48 | 1.50± 0.47 | 1.48± 0.49 | 1.54± 0.61 | 0.226 | 1.36±0.66 | 1.33±0.60 | 1.28±0.78 | 1.35±0.84 | 0.438 | 1.31± 0.57 | 1.31 ± 0.52 | 1.34 ± 0.50 | 1.37± 0.51 | ＜0.001 |

SES, social economic status; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglyceride; HDL-C, high density lipoprotein.

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**Figure S1 Association between MetS components and increased risk of ASCVD**