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Metabolic syndrome and its relation to dietary patterns among a selected urbanised and semi-urbanised Tibetan population in transition from nomadic to settled living environment

Wen Peng[1,*,†], Yan Liu[1,†], Maureen Malowany[2], Hongru Chen[1], Xiaodong Su[1] and Yongnian Liu[3]

[1]Department of Public Health, Medical College, Qinghai University, Xining, Qinghai 810008, China: [2]Braun School of Public Health and Community Medicine, Faculty of Medicine, Hebrew University of Jerusalem – Hadassah Medical Organization, Jerusalem 9112102, Israel: [3]Qinghai Health Development and Research Center, Xining, Qinghai 810008, China

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Abstract

Objective: To explore the scope of metabolic syndrome (MetS) and its relationship to the major dietary patterns among an urbanised and semi-urbanised Tibetan population in transition from nomadic to settled settings.

Design: Cross-sectional.

Setting: Community-based.

Participants: Urbanised and semi-urbanised Tibetan adults (*n* 920, aged 18–90 years), who have moved from nomadic to settled living environments, answered questionnaires on food consumption frequency and lifestyle characteristics through structured face-to-face interviews and completed anthropometric measurement and metabolic biomarker tests.

Results: MetS prevalence was 30·1 % in males and 32·1 % in females. Low HDL-cholesterol and central obesity were the leading metabolic abnormalities (86·3 and 55·8 %, respectively). Three major dietary patterns – urban, western and pastoral – were identified. Beef/mutton was an important food group for all three identified dietary patterns. In addition, the urban dietary pattern was characterised by frequent consumption of vegetables, tubers/roots and refined carbohydrates; the western pattern was characterised by sweetened drinks, snacks and desserts; and the pastoral pattern featured tsamba (roasted Tibetan barley), Tibetan cheese, butter tea/milk tea and whole-fat dairy foods. Individuals in the highest quintile of urban dietary pattern scores were found to be at a higher risk of developing MetS (OR 2·43, 95 % CI 1·41, 4·18) and central obesity (OR 1·91, 95 % CI 1·16, 3·14) after controlling for potential confounders.

Conclusions: MetS was common among urbanised and semi-urbanised Tibetan adult population in transition. The urban dietary pattern, in particular, was a risk factor for MetS. To prevent MetS, nutrition interventions need to be tailored to address the variety of local diet patterns to promote healthy eating.

Keywords
Dietary pattern
Metabolic syndrome
Tibetan nomads
Urbanisation
Central obesity

Metabolic syndrome (MetS) is defined as a cluster of metabolic disorders, including central obesity, elevated blood pressure (BP), increased blood glucose, elevated TAG and decreased HDL-cholesterol(1,2). MetS is associated with increased risk of CVD, which is the leading cause of mortality globally(3). According to data from the China Center of Disease Control (China CDC), people living on the Tibetan Plateau are among the populations with the highest mortality rates due to CVD in China(4). However, the reported prevalence of metabolic disorders among the Tibetan population (8·2–20·9 %)(5,6) was far below the national average data recorded in the 2010 China Non-communicable Disease Surveillance (33·9 %)(7). The reported prevalence was inconsistent with the high mortality rates due to CVD in Tibetan population. In addition, existing data were derived from indigenous Tibetan communities living in the

†These authors contributed equally to this work.

*Corresponding author: Email wen.peng2014@foxmail.com

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native environment, whether agricultural or pastoral. MetS prevalence among the urbanised and semi-urbanised Tibetan population, who are in transition from traditional nomadic to settled settings and may be at an increased risk of developing metabolic disorders[8], has never been reported.

Urbanisation is considered by public health researchers as an important risk factor for increased metabolic disorders[9]. The target population of the current study was a Tibetan population in transition from nomadic to settled settings in urban or suburban areas. They traditionally lived in pure pastoral zones on the Tibetan Plateau (usually >4000 m above sea level), with livestock husbandry as the only local food source. Since 2005, around 600 000 Tibetan nomads have moved, or partly moved, from their native nomadic environment and settled into urban or suburban areas. The moving and settling process is a result of grassland degradation due to environmental change and overgrazing in the headwater areas of Yangtze, Yellow and Mekong Rivers on the Tibetan Plateau[10–13]. In the newly formed urban or suburban settled communities, some community members have totally abandoned husbandry and are pursuing a living in the urban environment. Some have retained pastoral links, either by owning livestock under the care of others or by moving intermittently between urban and pastoral settings. The current urban food environment and lifestyle could consequently bring changes in metabolic disorders[10] among the population in transition, which cannot be captured by the existing data. Furthermore, the role of dietary patterns in metabolic disorders among the population is also unknown.

The objectives of the current study were: (i) to describe the prevalence of MetS and its components among the urbanised or semi-urbanised Tibetan population who were in transition from nomadic to settled settings; and (ii) to analyse the association between current dietary patterns and the diagnosis of MetS among this population in transition.

Methods

Surveyed community

This community-based cross-sectional study was conducted in two settled Tibetan communities in the suburb of Golmud City (2800 m above sea level), which is easily accessed by both the Qinghai–Tibetan railway and highway. The communities are also well connected to the central Golmud City by public buses. The settlement process began in 2007, and the population in receiving communities gradually increased. Until late 2018, the total Tibetan adult population reached almost 4000 in two communities. The pastoral indigenous communities, where the settled Tibetan population was originally from, were >4000 m above sea level. Due to the extreme altitude, the local traditional diet was livestock-based.

Subject enrolment

The survey was conducted together with a free health check-up programme focusing on common non-communicable diseases in community adults. Questionnaires, anthropometric measurements and biomarker tests were performed. The current study was conducted according to the Declaration of Helsinki and approved by the Ethics Committee of the Medical College, Qinghai University. Altogether 1003 community members who voluntarily registered for the check-up programme were also enrolled in the survey after verbal informed consent was received. Random sampling was not practical in the local setting. Nevertheless, the age and gender distribution between the participants and non-participating community adults, which was derived from the demographic data recorded in local governmental clinics, was similar.

The inclusion criteria for the current analysis were: (i) Tibetan adults aged ≥18 years; (ii) having completed anthropometric measurements, metabolic biomarker tests and the questionnaires, including demographic and lifestyle characteristics and dietary assessments; (iii) having no missing data on the required variables. In total, eighty-three subjects were excluded from analysis (age missing or <18 years, *n* 23; not Tibetan ethnicity, *n* 18; anthropometric measurement missing, *n* 36; biomarkers missing, *n* 3; incomplete FFQ, *n* 3). Finally, 920 subjects (419 males and 501 females) were included in the analysis.

Dietary assessments

A forty-one-item FFQ, modified from the FFQ used in the China Nutrition and Health Survey 2015[14], was utilised. Subjects enrolled were interviewed face-to-face by a trained investigator from a local community in the Tibetan language. Subjects were asked the consumption frequency of each food item in the previous year. The completed FFQs were reviewed again for quality control on the same day of the survey. A second face-to-face interview or a telephonic interview was used when necessary.

In the dietary analysis, we aggregated the forty-one food items into twenty-six food groups according to the similarity of nutrients and local dietary culture. We then regrouped the consumption frequency of each food group into three categories – daily basis (≥30 times per month), weekly basis (4–30 times per month) and monthly basis (1–4 times per month). Eating frequency less than once per month was not counted.

Demographic and lifestyle questionnaire

In the questionnaire, data on educational level (no schooling, <6 years of schooling, ≥6 years of schooling), type of medical insurance (urban, rural, no insurance), smoking status (never, former smoker, current <5 cigarettes/d, current ≥5 cigarettes/d), alcohol consumption (never, abstinence, <40 g/week, ≥40 g/week) and self-assessed physical activity (light, moderate, heavy) were collected. In the analysis, we used educational level and type of medical insurance as the proxy for socioeconomic status.

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Anthropometric and biomarker measurements

Waist circumference was measured at the mid-level between the costal margin and the iliac crest over light clothing. BP was measured in the right arm in sitting position, after at least 5 min of rest, using an electronic device (Panasonic EW3106). Waist circumference and BP were measured twice, and the mean values were utilised. Blood samples were collected after fasting overnight for at least 10 h. All blood specimens were processed and tested by the certified laboratory of the Second People's Hospital of Golmud. All metabolic biomarkers were measured using an automatic biochemical analyser (Beckman Coulter AU 480) with reagents from the same company (Sanwei Bio-engineering) using a standard procedure.

Definition and diagnostic criteria for metabolic syndrome

We used the revised NCEP ATP III criteria[2] for MetS with waist circumference cut-offs for the Asian population. Specifically, MetS was diagnosed when three or more of the following criteria were met: (a) central obesity: waist circumference ≥90 cm for males and ≥80 cm for females; (b) systolic BP ≥130 mmHg or diastolic BP ≥85 mmHg or on antihypertensive medication; (c) fasting plasma glucose (FBG) ≥5·6 mmol/l or on medication for high blood glucose; (d) HDL-cholesterol <1·03 mmol/l for males and <1·30 mmol/l for females or on medication for reduced HDL-cholesterol; (e) TAG ≥ 1·7 mmol/l or on medication for elevated TAG[1,2,15].

Composition of metabolic syndrome z-score

To describe and compare the continuous distribution of MetS components, we computed a summarised metabolic risk score (z-score) for each component of MetS[16]. The standardised z-score of each MetS component was computed by subtracting the sample mean from the individual value and then dividing by the SD of the sample mean for the parameters of waist circumference, BP (average of systolic and diastolic pressure), log-transformed TAG, log-transformed FBG and inverse HDL-cholesterol. z-Score computation for waist circumference and inverse HDL-cholesterol used sex-specific calculation[16]. The sum of z-scores from the five MetS components comprised the MetS z-score.

Statistical methods

Continuous variables were expressed as mean and SD, or mean and 95 % CI. The values for TAG and FBG were log-transformed before calculating the means and 95 % CI. Categorical variables were expressed as n and percentages. Student's t test or ANOVA were used to compare means. χ^2 test was used to compare percentages.

Principal component analysis with orthogonal transformation was used to identify the dietary patterns from FFQ. Three major dietary patterns were identified by the eigenvalues, Scree test and culinary interpretation. Every subject received a factor score for each of the three dietary patterns. The resulting three sets of factor scores (dietary pattern scores) were standardised and independent.

Pearson partial correlation analysis was applied for the correlations between dietary pattern scores and metabolic parameters composing MetS after controlling for gender, age (years), education, medical insurance, smoking, alcohol and physical activity. Logistic regression was used to acquire crude and adjusted OR for MetS, and to assess the overall trend of OR across the increasing quintiles of each set of dietary pattern scores. The median of each quintile of dietary pattern scores was used for the trend analysis. $P < 0·05$ was considered statistically significant. All statistical analyses were conducted with SPSS (version 18.0).

Results

Demographic and lifestyle characteristics

Table 1 shows the demographic and lifestyle characteristics of the 920 subjects included in the study. Among the 920 subjects aged 18–90 years, the educational level was generally low, with 682 (74·1 %) participants never having attended schools. Males were slightly better educated than females ($P = 0·001$). Males also had higher rates of smoking and alcohol consumption, but less physical activity, than females (all three P values <0·001).

Metabolic syndrome and its components

The prevalence of MetS among participants was 31·2 % (n 287), with no statistical difference between males and females (30·1 v. 32·1 %; $P = 0·501$). Low HDL-cholesterol and central obesity were the leading abnormalities (86·3 and 55·8 %, respectively). Nevertheless, the prevalence of individual MetS components between genders was different. As shown in Fig 1(a), the percentages of central obesity and low HDL-cholesterol were significantly higher in females than in males (central obesity 64·5 v. 45·3 %; low HDL-cholesterol 91·8 v. 79·7 %; both P values <0·001). By contrast, more males than females had higher TAG (16·7 v. 7·8 %; $P < 0·001$).

Then we compared MetS z-scores between genders. The average z-score for males was significantly higher than for females (mean and 95 % CI – males 0·41 (0·11, 0·71) v. females –0·34 (–0·62, –0·06); $P < 0·001$; Fig 1(b)). The mean and 95 % CI of MetS components are shown in online Supplemental Table S1.

Three major dietary patterns identified in relation to demographic and lifestyle factors

Table 2 shows the three major dietary patterns identified using principal component analysis. The first, urban dietary pattern, was characterised by a frequent consumption of vegetables, tubers and roots, onions and spring onions (as condiments), and refined carbohydrates. The second, western dietary pattern, was characterised by a frequent

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Table 1 Demographic and lifestyle characteristics of subjects in urbanised settled Tibetan communities

	Total (*n* 920)		Male (*n* 419)		Female (*n* 501)		
	n	%	*n*	%	*n*	%	*P*
Age (years)							
Mean	43·2		43·5		43·0		0·558
SD	13·9		14·2		13·6		
Education							
No schooling	682	74·1	285	68·0	397	79·2	0·001**
<6 years of schooling	95	10·3	52	12·4	43	8·6	
≥6 years of schooling	143	15·5	82	19·6	61	12·2	
Medical insurance							
Urban insurance	460	50·0	209	49·9	251	50·1	0·274
Rural insurance	443	48·2	199	47·5	244	48·7	
No insurance	17	1·8	11	2·6	6	1·2	
Smoking status							
Never	666	72·4	207	49·4	459	91·6	<0·001***
Former smoker	88	9·6	80	19·1	8	1·6	
Current, <5 cigarettes/d	30	3·3	21	5·0	9	1·8	
Current, ≥5 cigarettes/d	136	14·8	111	26·5	25	5·0	
Alcohol							
Never	723	78·6	265	63·2	458	91·4	<0·001***
Abstinence	93	10·1	79	18·9	14	2·8	
<40 g/week	91	9·9	64	15·3	27	5·4	
≥40 g/week	13	1·4	11	2·6	2	0·4	
Physical activity							
Light	617	67·1	303	72·3	314	62·7	<0·001***
Moderate	158	17·2	84	20·0	74	14·8	
Heavy	145	15·8	32	7·6	113	22·6	

**$P < 0·01$, ***$P < 0·001$.

intake of sweetened drinks, snacks and desserts. The third, pastoral dietary pattern, was characterised by tsamba (roasted Tibetan barley), Tibetan cheese, butter tea/milk tea and whole-fat dairy. Total variance explained by the three dietary patterns was 28·1 %.

In addition, beef and mutton were frequently consumed by the majority of participants. A high number of participants (89·9 %) consumed beef and mutton at least once per day, despite the relatively low factor loading values in all three dietary patterns. Thus, beef and mutton form an important food group in all the three identified dietary patterns.

We then compared the demographic and lifestyle characteristics among participants in the lowest (Q1), middle (Q3) and highest (Q5) quintiles in each set of the three dietary pattern scores. Among the subjects in the Q1, Q3 and Q5 quintiles in western dietary pattern scores, the age monotonically and significantly decreased (50·1 ± 12·3, 44·0 ± 13·3 and 36·2 ± 13·1 years, respectively; P_{trend} <0·001). By contrast, the subjects scoring in the Q5 and Q3 quintiles in pastoral pattern scores were almost 10 years older than those in the Q1 quintile (45·7 ± 13·7, 45·7 ± 13·2 and 36·3 ± 13·0 years, respectively; P_{trend} <0·01). The details are shown in online Supplemental Table S2.

Association between dietary patterns and metabolic syndrome

We conducted Pearson partial correlation analysis to see the correlation between each set of dietary pattern scores and MetS *z*-score as well as MetS components. The urban dietary pattern was positively correlated with MetS *z*-score after adjustment ($\rho = 0·099$; $P_{adjusted} = 0·003$). A further analysis revealed that the urban dietary pattern score was also positively correlated with waist circumference ($\rho = 0·085$; $P_{adjusted} = 0·011$), and negatively correlated with HDL-cholesterol ($\rho = -0·075$; $P_{adjusted} = 0·024$) after adjustment. Log-transformed FBG showed a negative partial correlation with pastoral dietary pattern scores ($\rho = -0·069$; $P_{adjusted} = 0·038$). Detailed data for the correlation analysis are provided in online Supplemental Table S3.

Further, a logistic regression was used in analysing the association between MetS and each set of dietary pattern scores. As shown in Table 3, among the subjects in the lowest (Q1), middle (Q3) and highest (Q5) quintiles of urban dietary pattern scores, the OR for MetS monotonically increased, in crude values and in three different models adjusted for potential confounders (all four P_{trend} <0·05). The risks of developing MetS in individuals in the highest quintile (Q5) of urban pattern scores were 2·43 times higher than those in the lowest quintile (Q1) after adjusting for all the inclusive confounders (model 3 in Table 3). The same analysis was also performed for western and pastoral dietary patterns. However, no significant association was observed after controlling for confounders.

Then, adjusted OR for each MetS component by quintiles of the three dietary pattern scores were calculated using a fully controlled model 3 (Table 4). The likelihood of being centrally obese monotonically increased across the Q1, Q3 and Q5 quintiles of urban pattern scores ($P_{trend} = 0·015$). A similar trend was observed in the urban

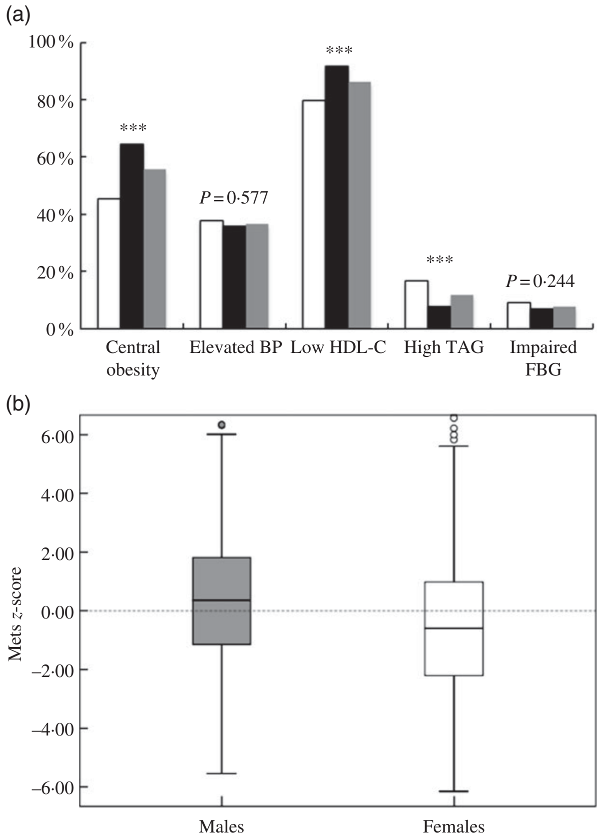

Fig. 1 (colour online) Distribution of metabolic syndrome (MetS) and its components between genders. (a) Percentage of MetS components between genders. χ^2 test was used to compare the percentages between males and females. ***$P < 0·001$. □, males; ■, females; ■, total. (b) Distribution of MetS *z*-score between genders. $P < 0·001$ between males and females

Table 2 Three major dietary patterns identified among subjects in urbanised settled Tibetan communities

		Urban pattern	Western pattern	Pastoral pattern
		Factor 1	Factor 2	Factor 3
1	Light vegetables	**0·737**	0·174	0·019
2	Dark vegetables	**0·706**	0·198	–0·061
3	Tubers and roots	**0·646**	0·171	–0·036
4	Onion and spring onion	**0·587**	0·05	–0·100
5	Refined carbohydrates	**0·458**	–0·021	–0·012
6	Mushrooms	**0·445**	0·245	0·083
7	Sweetened drinks	0·073	**0·577**	–0·162
8	Nut and seeds	0·084	**0·541**	–0·084
9	Salty snacks	–0·068	**0·528**	0·034
10	Desserts	0·049	**0·478**	0·212
11	Eggs	0·228	**0·468**	–0·007
12	Poultry and fish	0·166	**0·416**	–0·037
13	Pulses	0·132	**0·401**	–0·11
14	Fried carbohydrates	–0·152	**0·396**	0·151
15	Tsamba	0·036	–0·188	**0·763**
16	Tibetan cheese	0·116	–0·144	**0·729**
17	Butter tea and milk tea	0·007	0·058	**0·527**
18	Whole-fat dairy	–0·201	0·293	**0·422**
19	Processed meat	0·221	0·372	–0·169
20	Fresh fruits	0·234	0·369	0·166
21	Pork	0·271	0·255	–0·229
22	Organ meat	–0·039	0·257	0·192
23	Non-caloric drink (water, tea)	0·282	–0·127	–0·07
24	Beef and mutton	0·206	–0·009	0·15
25	Whole grains	0·251	0·067	0·087
26	Processed vegetables	0·031	0·258	–0·024
Total variance explained		10·659	10·16	7·262

Absolute values >0·38 are shown in bold.

dietary pattern for low HDL-cholesterol, with a marginal statistical significance ($P_{trend} = 0·050$). In addition, in western dietary pattern scores, the OR for central obesity increased monotonically in the Q1, Q3 and Q5 quintiles, despite that P_{trend} was slightly lower than the significance level ($P_{trend} = 0·066$).

Discussion

The current study revealed that MetS prevalence in surveyed communities was high (31·2 %). Among the five components of MetS, low HDL-cholesterol was most common, followed by central obesity and elevated BP. The urban dietary pattern, characterised by frequent intakes of beef/mutton, vegetables, tubes/roots and refined carbohydrates, was positively associated with MetS. The current study, to our knowledge, is probably the first to describe the high prevalence of MetS and its components among this unique population in transition from traditional nomadic to settled urban or semi-urban lifestyles, and further analysed the association between major dietary patterns and MetS in this population in transition.

Metabolic syndrome prevalence

The reported MetS prevalence in the target population (males 30·1 %; females 32·1 %) is similar to the data from a nationally representative Chinese population (males 31·0 %; females 36·8 %)[7], but was remarkably higher than the earlier data from a Tibetan population in China under various settings, ranging from 8 to 11·3 %[5,17,18]. A recent survey involving a small sample of a Tibetan population in India suggested higher MetS prevalence than shown by previous reports (males 10·6 %; females 33·3 %)[19]. The variation in MetS prevalence and related metabolic disorders over the years was in line with the secular trends observed in other Asia Pacific populations[20]. Moreover, differences in demographic characteristics, living environments (altitude, agricultural or pastoral zone, rural or urban), criteria for MetS diagnosis (IDF, NCEP ATP III, etc.) and the sampling framework also affected the reported prevalence. A unique feature of the Tibetan population in the current study was a rapid environment transition from the native nomadic setting to the urban or semi-urban setting[10]. The subsequent nutritional transition and epidemiological transition[9] could explain a high MetS prevalence in the target population.

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Table 3 OR of metabolic syndrome by quintiles of major dietary pattern scores in urbanised settled Tibetan communities†

	Q1 (lowest) (*n* 184)	Q3 (middle) (*n* 184)			Q5 (highest) (*n* 184)			
	OR	OR	95 % CI		OR	95 % CI		P_{trend}
Urban dietary pattern	Median = −1·38	Median = 0·05			Median = 1·31			
Crude	1	1·17	0·75	1·84	1·68	1·08	2·62	0·021*
Model 1	1	1·44	0·87	2·38	2·45	1·49	4·04	<0·001***
Model 2	1	1·39	0·83	2·31	2·44	1·42	4·19	0·001**
Model 3	1	1·38	0·83	2·30	2·43	1·41	4·18	0·002**
Western dietary pattern	Median = −1·20	Median = −0·12			Median = 1·37			
Crude	1	0·67	0·44	1·04	0·57	0·37	0·89	0·016*
Model 1	1	0·98	0·60	1·58	1·43	0·84	2·41	0·180
Model 2	1	0·96	0·59	1·57	1·28	0·75	2·20	0·357
Model 3	1	0·97	0·59	1·57	1·27	0·74	2·18	0·377
Pastoral dietary pattern	Median = −1·48	Median = 0·27			Median = 1·02			
Crude	1	1·91	1·18	3·10	2·06	1·27	3·33	0·002**
Model 1	1	1·04	0·61	1·79	1·13	0·66	1·94	0·671
Model 2	1	1·23	0·70	2·16	1·35	0·76	2·38	0·306
Model 3	1	1·23	0·70	2·16	1·35	0·76	2·40	0·300

*$P < 0·05$, ** $P < 0·01$, ***$P < 0·001$.
†Model 1: adjusted for gender, age (years). Model 2: additionally adjusted for education (no schooling, <6 years of schooling, ≥6 years of schooling), insurance (urban, rural, no insurance), smoking (never, former, current <5 cigarettes/d, current ≥5 cigarettes/d), alcohol (never, abstinence, current <40 g/week, current ≥40 g/week). Model 3: further adjusted for physical activity (light, moderate, heavy).

Table 4 Adjusted OR of components of metabolic syndrome by quintiles of major dietary pattern scores in urbanised settled Tibetan communities‡

	Q1 (lowest), *n* 184	Q3 (middle), *n* 184			Q5 (highest), *n* 184			
	OR	OR	95 % CI		OR	95 % CI		P_{trend}
Urban dietary pattern	Median = −1·38	Median = 0·05			Median = 1·31			
Central obesity	1	1·04	0·66	1·65	1·91	1·16	3·14	0·015*
Elevated blood pressure	1	1·36	0·84	2·21	1·60	0·96	2·66	0·070
Low HDL-cholesterol	1	1·30	0·71	2·38	2·00	1·00	3·99	0·050†
Elevated TAG	1	1·02	0·50	2·09	0·96	0·44	2·11	0·934
Impaired FBG	1	2·36	1·10	5·10	1·07	0·42	2·75	0·642
Western dietary pattern	Median = −1·20	Median = −0·12			Median = 1·37			
Central obesity	1	1·61	1·00	2·58	1·67	0·99	2·80	0·066
Elevated blood pressure	1	1·01	0·63	1·60	1·35	0·81	2·24	0·241
Low HDL-cholesterol	1	0·90	0·48	1·69	0·85	0·42	1·72	0·651
Elevated TAG	1	1·04	0·50	2·15	1·13	0·51	2·48	0·763
Impaired FBG	1	0·62	0·30	1·29	0·59	0·24	1·46	0·198
Pastoral dietary pattern	Median = −1·48	Median = 0·27			Median = 1·02			
Central obesity	1	1·22	0·76	1·97	1·18	0·73	1·93	0·443
Elevated blood pressure	1	0·78	0·46	1·30	0·86	0·51	1·46	0·506
Low HDL-cholesterol	1	1·32	0·68	2·57	1·38	0·70	2·75	0·326
Elevated TAG	1	1·14	0·50	2·58	1·07	0·45	2·51	0·850
Impaired FBG	1	0·71	0·29	1·75	0·56	0·21	1·46	0·237

FBG, fasting blood glucose.
*$P_{trend} < 0·05$; †$P_{trend} = 0·05$.
‡Adjusted OR was derived after controlling for gender, age (years), education (no schooling, <6 years of schooling, ≥6 years of schooling), medical insurance (urban, rural, no insurance), smoking (never, former, current <5 cigarettes/d, current ≥5 cigarettes/d), alcohol (never, abstinence, current <40 g/week, current ≥40 g/week) and physical activity (light, moderate, heavy).

Among the five MetS components in the NCEP ATP III definition, studies from different research groups, including ours, agreed on the high prevalence of central obesity and hypertension in the Tibetan population[5,6,17]. The reported prevalence of central obesity ranges from 41·2 to 55·8 %[5,17], while that of hypertension ranges from 32·5 to 62·4 %[5,6,17]. The most prevailing MetS components underscore the need for urgent public health interventions.

Major dietary patterns identified

The major dietary patterns identified by the current study were quite different from those identified by earlier studies among Tibetan[21,22] or other populations[23]. The three identified patterns reflect mixed influences from the urban setting, the food industry and mass media, and the traditional pastoral dietary culture, respectively. The identified variable dietary patterns reflect the complexity of the

Public Health Nutrition

population in transition, with regard to residence, food environment and, subsequently, dietary habits.

Among the three, the urban dietary pattern was similar to the mainstream Chinese traditional diet. Food groups in this pattern, despite not originally from a nomadic dietary culture, have diversified local diets and could increase the resilience in food security[24,25]. This food diversification should be acknowledged as a positive contribution to public health nutrition introduced or made available in this urban setting.

The younger age of subjects in the highest quintile of western dietary pattern scores indicates the popularity of western diets among the young generation. Emerging western diets among indigenous people have been studied previously in other populations (e.g. Arctic people)[26]. Among the Tibetan population, Dickerson *et al.*[27] reported the westernisation of Tibetan traditional diets using qualitative methods. The present study is perhaps the first to report this phenomenon using quantitative methods. The quantitative methods provided sensitive measurements that helped in identifying the subpopulation (e.g. the young), which scored higher in the western dietary pattern, thus allowing for a better-informed and relevant intervention design in public health practice. The emerging western diet among young people is also occurring in other populations, such as adolescents, with the erosion of the Mediterranean diet[28], or among youth in East Europe exposed to westernised diets[29].

The identified pastoral dietary pattern in the current study was very different from the dietary patterns identified in the Tibetan population from semi-agricultural/pastoral zones[21,22], which was explained by the distinct native environments. The target population was originally from pure pastoral zones >4000 m above sea level, with livestock husbandry as the only local food source[10]. By comparison, previous studies have been conducted in semi-agricultural/pastoral zones with both farming and husbandry as local food sources[21,22], which may provide more diversified food groups. The differences in native food environment and the corresponding traditional food system and dietary culture were responsible for the distinctions[30,31]. In fact, the unique pastoral dietary pattern identified in the target population, which has not been described previously, highlights the necessity for future public health research.

Dietary pattern and health outcomes

The urban dietary pattern, characterised by frequent intakes of beef/mutton, vegetables, tubers and roots, and refined carbohydrates, was positively associated with MetS and its components, including central obesity and low HDL-cholesterol. This finding was surprising as dietary patterns rich in vegetables are generally associated with less metabolic disorders[32–36]. The counterintuitive results could be explained by the presence of other food groups in this pattern (e.g. red meat, refined carbohydrates). Further, despite the high consumption of vegetables in the urban dietary pattern, local diets remain red meat-based, with 89·9 % of study participants recording daily beef/mutton consumption. Given the consistently high intakes of beef/mutton in the majority of participants, this food group could not be distinguished by the principal component analysis. The evidence for a positive association between red meat or refined carbohydrate consumption and MetS was provided from different populations[37,38]. Higher refined carbohydrate intakes were also suggested to be associated with higher waist circumference, higher BP, elevated FBG and higher serum TAG in an Asian population[38]. The negative health impact of red meat and refined carbohydrate consumption in the urban pattern may have exceeded the health benefits from vegetables, which could explain the positive association between the urban dietary pattern and MetS.

In addition, the correlation analysis showed a weak but significant partial correlation between urban dietary scores and MetS *z*-score as well as MetS components (waist circumference, HDL-cholesterol) ($\rho = -0{\cdot}075$ to $0{\cdot}099$, $P_{\text{adjusted}} < 0{\cdot}05$). This result is in line with the associations revealed by the logistic regression analysis, which support a genuine weak relationship rather than a correlation by chance.

The western dietary pattern was not associated with MetS, but was positively associated with central obesity at a marginal level ($P = 0{\cdot}066$) in the target population. Other studies have shown a positive association between western diets and obesity[39,40]. In the target population, a significant positive association may also appear with an increased sample size, which could be confirmed by further studies.

Limitations

Some limitations existed in the study. First, the enrolment of participants was based on voluntary participation rather than random sampling. However, the age and gender distribution of participants was similar to non-participating community adults. Therefore, community representativeness could be inferred. Second, dietary assessments considered data only on the frequency of food intakes without recording portion size. Nevertheless, previous studies have shown that portion sizes are usually poorly measured in FFQ, and frequency rather than portion size mattered most for interpersonal variation[41]. Third, the cross-sectional design can only generate an association rather than causation. Fourth, some arbitrary decisions were made in the dietary pattern analysis using the principal component analysis in, for example, the food grouping process. Fifth, the physical activity questionnaire used a self-assessed approach and was not validated. Sixth, patients with a diagnosis of diabetes, hypertension and dyslipidaemia were not excluded, while these conditions may affect dietary choices. Nevertheless, nutrition literacy, which is necessary

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for self-management[42], was probably very low in the target population in which 74·1 % of participants had no schooling. Thus, the target population probably had very limited dietary modification even after being diagnosed with those medical conditions.

In conclusion, our study suggests that MetS prevalence in the urban and semi-urban Tibetan populations, who are in transition from nomadic to settled urban lifestyles, was high. The study population demonstrated a mixed pattern of urban, western and traditional pastoral diets. In addition, the urban dietary pattern was positively associated with central obesity, low HDL-cholesterol and, further, MetS. Nutrition interventions are recommended to be tailored to address the variety of local diet patterns to promote healthy eating, thus decreasing the burden of CVD.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980019004798

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