Original Article

Major dietary patterns and their relationship to obesity among urbanized adult Tibetan pastoralists

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Background and Objectives: This study investigated major dietary patterns and their relationship to obesity among urbanized Tibetan pastoralists. **Methods and Study Design:** Using a cross-sectional design, this study assessed 782 urbanized Tibetan pastoralists aged 18-84 y. A food frequency questionnaire and anthropometric measurements were conducted in 2018. Principal component analysis was used to identify dietary patterns. Logistic regression was applied to compare the risks for overweight (BMI ≥24 kg/m^2), obesity (BMI ≥28 kg/m^2), and central obesity (waist circumference ≥80 cm for women and ≥85 cm for men) across quintiles of dietary pattern scores after controlling for gender, age, education, medical insurance, smoking status, alcohol consumption and physical activity. **Results:** This study identified three major dietary patterns: an urban pattern characterized by high intake of vegetables, tubers/roots, and refined carbohydrates; a western pattern characterized by sugary drinks, snacks, and desserts; and a pastoral pattern characterized by *tsamba* (roasted Tibetan barley), Tibetan cheese, and buttered/milk tea. Subjects in the highest quintile of urban pattern scores were more likely to be overweight (OR=2.58, 95% CI 1.48-4.49) (*p*-for-trend=0.001), obese (2.94, 1.57-5.49) (*p*-for-trend=0.001), and centrally obese (1.94, 1.12-3.36) (*p*-for-trend=0.019) compared to those in the lowest quintile with confounders controlled. The western dietary pattern was positively associated with overweight (*p*-for-trend=0.037). No clear association was observed for the pastoral dietary pattern. **Conclusions:** Urban and western dietary patterns independently predict the likelihood of being overweight. Improved nutrition education may contribute to healthier eating behaviors, thus reducing or preventing obesity.

Key Words: dietary pattern, overweight/obesity, nutrition transition, Tibetan pastoralists, urbanization

INTRODUCTION

Obesity, as an important risk factor for many non-communicable diseases, has become a global public health challenge,[1,2] particularly among the populations undergoing rapid dietary transition in the developing world.[3] An upward trend in obesity, associated with dietary and lifestyle transition, has been reported in indigenous populations, including in Arctic peoples[4] and indigenous Australians.[5] Regarding the prevalence of obesity and other risk factors for cardiovascular disease among Tibetan population, [6-8] in previous studies, more than one third of individuals were classified as overweight or obese,[6] while the prevalence of abdominal obesity was 46%.[7] Urbanization is a strong driver of dietary and lifestyle transition, and also contributes to the prevalence of obesity.[3] Within the Tibetan population, a possible association between dietary patterns and obesity has not yet been explored.

Tibetan pastoralists living on the Tibetan Plateau constitute a population that is experiencing rapid urbanization and, in all likelihood, dietary transition. From 2005 to 2014, nearly 600000 Tibetan pastoralists left high-altitude pasture areas and settled in urban or suburban areas primarily because of the environmental pressures caused by climate change and grassland degradation in the headwater areas of some important rivers on the Tibetan Plateau.[9] In this article, the term "urban settled communities" is used for such communities. This urbanization process is ongoing and will increasingly implicate local Tibetan pastoralists. Changes in food environment and lifestyle in these urban settings have likely affected the dietary patterns of Tibetan pastoralists and subsequently the health outcomes of diet-related disease.

Traditionally, Tibetan food comes primarily from the local environment, with distinct patterns in agricultural and pastoral zones[10] due to differing food availability in the natural environment. Previous research has described the Tibetan diet from an anthropological[11,12] or public health perspective.[10,13-15] However, these studies have typically focused solely on agricultural or semi-agricultural zones, whereas the purely pastoral Tibetan

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diet has not been well documented. From the limited literature available[10,12] as well as our own field investigation, we could conclude that the traditional food available in pastoral zones, which are typically above 4000 m in altitude, is largely livestock based. The traditional pastoral diet is composed primarily of locally produced meat from yak and mutton, dairy products and the trading-source *tsamba* (roasted Tibetan barley) and black tea. To date, we have not found any literature that describes possible dietary changes among Tibetan pastoralists in urban settled communities.

We performed a cross-sectional survey in two urban settled Tibetan communities, the populations of which were originally from the pure pastoral zones above 4200 m in altitude. The objectives of this study were (1) to document current dietary patterns among Tibetan pastoralists in urban settled communities and (2) to explore the possible association between dietary patterns and the likelihood of such populations of being overweight or obese.

METHODS

Participants

This cross-sectional study was conducted in two urban settled Tibetan communities in the suburbs of Golmud, which is the third largest city on the Tibetan Plateau and is located at an elevation of 2800 m above sea level. In addition, Golmud is accessible by both the Qinghai-Tibet railway and the Qinghai-Tibet highway, which allow inhabitants access to markets and merchandise from lowland areas. Both communities are located 8 km from the downtown area of Golmud, and access to this area is easy by public buses. The settlement of both communities commenced in 2007; since then, the adult population has increased to nearly 4000. Figure 1 indicates the location of the two communities.

From November 2018 to December 2018, a health survey related to non-communicable disease was conducted among adult community members. Participants also completed demographic and lifestyle questionnaires as well as dietary assessments using food frequency questionnaires (FFQs). Anthropometric and some metabolic biomarker measurements were also gathered. The study was approved by the ethics committee of the Medical College in Qinghai University. In total, 1003 adults voluntarily registered to participate and were enrolled in the survey, and these adults accounted for more than 25% of the total adult population in the two communities. Oral informed consents were obtained before participating. The age and gender characteristics of study participants did not significantly differ from the demographic data available for the total adult populations within the communities studied.

The inclusion criteria for analysis in this study were as follows: (1) Tibetan and aged 18 y or older, (2) with completed FFQs and anthropometric measurements, (3) completed information provided regarding important demographic and lifestyle features, and (4) no reported history of diabetes, hypertension, dyslipidemia or stroke. After exclusion, the analysis included 782 participants, consisting of 340 men and 442 women. A flowchart on the inclusion process is provided in Supplementary Figure 1.

Dietary assessments

We conducted dietary assessments with a 41-item FFQ, which was modified from the FFQ used in the China Nutrition and Health Survey 2015.[16] Participants were interviewed face to face by a trained field investigator from the local community who could speak Tibetan. Participants reported their frequency of consumption of each food item throughout the past year. Given the absence of a standard portion size in participants' dietary culture and the overall low literacy of participants, we did not collect information on the portion sizes of the food items. Each FFQ was reviewed on the day surveyed for quality control. Answers that were questioned were confirmed again by a second face-to-face or phone interview. To define dietary patterns, we aggregated the 41 food items into 24 food groups based on similarity of nutrients and cultural culinary use. Items of "packaged vegetables (canned, dried, pickled, or fermented)" and "onions and garlic" in the FFQ were excluded in the grouping process because of the low frequency of consumption or small amount of

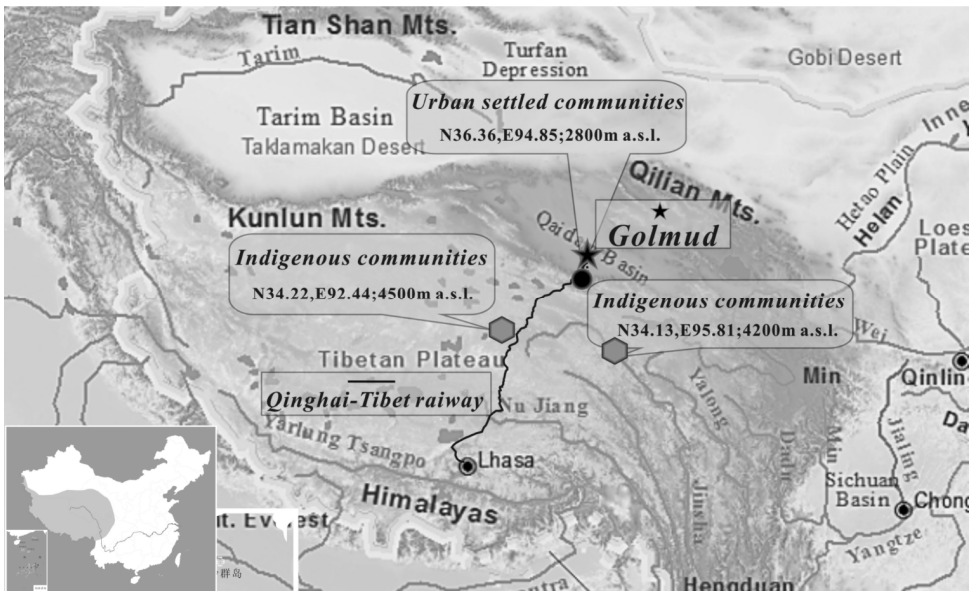

Figure 1. Location of the urban settled communities and indigenous communities on the Tibetan Plateau

consumption. Among the participants, 85% did not consume packaged vegetables or consumed this food group less than once per month; whereas onions and garlic were consumed as condiments in minimal amounts as parts of culinary dishes. Some individual foods were listed as a single food group (e.g. *tsamba* and eggs) because of their unique nutrient profiles or cultural culinary use. To minimize the effect of ambiguous recall on the retrospective dietary assessments, each food group was categorized into one of three groups according to its frequency of consumption: daily (≥ once per day), weekly (1-6 times per week), or monthly (1-3 times per month).

Anthropometric measurements

Both weight and height were measured using the same calibrated electronical device (Kangjian, HGM-200, Jiangsu, China). Weight was measured to the nearest 100 g with participants wearing light clothes and no shoes. Height was measured with participants standing in a normal position without shoes. Waist circumference was measured at the midpoint between the costal margin and the iliac crest over light clothing, and hip circumference was measured at the widest diameter to the nearest centimeter. All the anthropometric measurements were performed by staff members of a local clinic who had received appropriate training. Measurements were taken twice, with the mean value used. BMI was calculated as weight (kg) divided by height squared (m^2). In this study, the classifications of overweight and obese were defined as BMI ≥24 and ≥28 kg/m^2, respectively, according to the criteria of the Working Group on Obesity in China (WGOC).[17] Central obesity was defined as having a waist circumference of ≥80 cm for women and ≥85 cm for men—also based on the WGOC criteria,[17] and central adiposity was defined as having a waist-hip ratio (WHR) of ≥0.85 for women and ≥0.90 for men, according to a WHO expert consultation report in 2008.[18]

Assessments of other variables

Other demographic variables, lifestyle factors and relative history were obtained through the face-to-face interviews. Educational attainment, type of medical insurance, smoking status, alcohol consumption, and physical activity were quantified as categorical variables according to specific examples in the questionnaires. Specifically, educational attainment was defined as either no schooling, <6 y of schooling, or ≥6 y of schooling; type of medical insurance was grouped into urban, rural or no insurance; smoking status was classified as never, quit, <5 cigarettes/d, or ≥5 cigarettes/d; alcohol consumption was grouped into never, abstinence, <40 g/wk, or ≥40 g/wk; and physical activity was grouped into one of three self-assessed categories of light, moderate, or heavy. We failed to obtain information regarding screen time in the pilot survey, because most community members could not answer this question in a quantitative or semi-quantitative manner. As a result, we removed this question from the questionnaire. Information on family income was requested in the questionnaire; however, participants were likely to underreport their family income [19] probably due to the concern that whether reported income would interfere the amount of subsidies they could receive from government. Given this possibility, we exclude this variable from subsequent analysis. Instead, educational attainment and medical insurance were used as proxies for social economic status.

Statistical methods

The outcome variables, including BMI, waist circumference, and WHR, were analyzed as continuous variables. These variables were also grouped as binominal variables using the criteria stated in the previous anthropometric measurements section. Among the potential confounding factors, age was treated as a continuous variable, whereas gender, education, type of medical insurance, smoking status, alcohol consumption, and physical activity were treated as categorical variables.

Principal component analysis (PCA) with orthogonal varimax rotation was used to identify major dietary patterns, meaning that the three sets of factor scores for the identified dietary patterns were considered to be standardized and independent. We used a cutoff value of 0.44 for factor loadings to identify the food items that contributed to a factor. Three dietary patterns emerged and were identified by their eigenvalues, with a Scree test, and also through natural interpretation. Every participant subsequently received a factor score for each of the three identified patterns.

To compare demographic variables, lifestyle factors, and obesity parameters among dietary patterns, participants were categorized into quintiles based on their dietary pattern scores. ANOVA or chi-square testing was applied as appropriate. General linear modeling was used to compare the BMI, waist circumference, and WHR of individuals across the quintiles of dietary pattern scores; different models were adjusted by gender, age, education, type of medical insurance, smoking status, alcohol consumption, and physical activity. Logistic regression was used to obtain adjusted ORs, and to assess the overall OR trends for overweight, obesity, central obesity and central adiposity across the quintiles while simultaneously controlling for confounding factors. A p value of <0.05 was considered statistically significant. All statistical analyses were performed with SPSS (version 20.0, Chicago, IL, USA).

RESULTS

Of the 782 participants, 340 (43.5%) were men, and 442 (56.5%) were women. The age (mean±standard deviation) of the participants was 41.5±13.3 y, ranging from 18 to 84 y old. Educational attainment was overall low, with 584 (74.7%) participants having received no schooling, 71 (9.1%) having received less than 6 y of schooling, and only 127 (16.2%) having received at least 6 y of schooling. The demographic and lifestyle characteristics of the participants are available in Supplementary table 1.

Within the study group, the percentage of participants who were classified as having overweight, obesity, central obesity and central adiposity was high (58.4% overweight, 26.6% obesity, 59.0% central obesity, and 59.5% central adiposity), with no significant difference between genders. The body weights, waist circumferences and WHRs of participants are available in Supplementary table 2.

Table 1. Factor-loading matrix for the 3 major dietary patterns

	Urban diet (factor 1)	Western diet (factor 2)	Pastoral diet (factor 3)
Light vegetables	0.74†	0.16	-0.01
Dark vegetables	0.72†	0.14	-0.08
Tubers & roots	0.67†	0.13	-0.04
Mushrooms	0.49†	0.22	0.06
Refined carbohydrates	0.44†	-0.01	0.01
Sugary drinks	0.09	0.57†	-0.15
Nut & seeds	0.07	0.56†	-0.08
Snacks salty	-0.07	0.53†	0.08
Eggs	0.26	0.47†	0.00
Desserts	0.10	0.45†	0.26
Tsamba	0.07	-0.22	0.75†
Cheese	0.15	-0.16	0.72†
Buttered tea & milk tea	-0.04	0.04	0.53†
Whole fat dairy	-0.21	0.26	0.46†
Water & tea	0.31	-0.13	-0.07
Fresh fruits	0.30	0.30	0.16
Pork	0.27	0.27	-0.25
Whole grains	0.26	0.09	0.11
Processed meat	0.21	0.40	-0.15
Poultry & fish	0.19	0.39	-0.07
Beef & mutton	0.15	-0.01	0.17
Legumes	0.12	0.40	-0.12
Organ meat	-0.07	0.25	0.21
Fried carbohydrates	-0.16	0.40	0.16
Total variance explained	14.0%	8.0%	7.1%

†Absolute values ≥0.44.

Three major dietary patterns were identified through PCA (Table 1). The first pattern, labeled as an urban dietary pattern, was characterized by high consumption of vegetables, tubers/roots, and refined carbohydrates. The second pattern, labeled as a western dietary pattern, was characterized by high consumption of sugary drinks, snacks, eggs, and desserts. The third pattern, labeled as pastoral dietary pattern, was characterized by high consumption of *tsamba*, Tibetan cheese, traditional Tibetan drinks (buttered tea or milk tea), and whole-fat dairy products. Altogether, the three patterns explained 29.0% of the total variance.

Although the factor loadings for the beef/mutton group were not high in any of the three dietary patterns (all were <0.2), this food group was consumed by 90.3% of participants at least once per day, making it the food group with the highest frequency.

The factor scores of each dietary pattern were divided into quintiles. Participants in the highest quintiles (Q5) of western pattern scores were 15 y younger than those in the lowest quintile (Q1), and this trend was reversed for the pastoral pattern scores (Q5-Q1 was 8.4 y) (both $p<0.001$) (Table 2). Other demographic and lifestyle characteristics were compared across the quintiles of each dietary pattern score (Table 2).

Table 3 presents the multivariate adjusted means for BMI, waist circumference, and WHR across the quintiles of the three dietary patterns. With gender, age, education, medical insurance, smoking status, alcohol consumption (in Model 2), and physical activity (in Model 3) controlled, both BMI and waist circumference increased monotonically from the lowest (Q1) to the highest quintile (Q5) for urban pattern scores ($p<0.05$). With regard to the western pattern scores in Model 2 and Model 3, BMI and waist circumference in the highest quintile (Q5) were higher than those in the lowest quintile (Q1), but this result was not significant. For the pastoral pattern scores, no clear association was found.

Table 4 presents the ORs for being overweight, obese, and centrally obese across the quintiles of dietary pattern scores. For the urban dietary pattern, the ORs for being overweight and obese increased monotonically across the lowest (Q1), the middle (Q3) and the highest quintiles (Q5) of pattern scores, after the confounding variables were controlled in all three models (all six *p*-for-trend <0.01). In the fully adjusted Model 3, participants in the highest quintile (Q5) of urban pattern scores were more likely to be overweight (OR=2.58, 95% CI 1.48-4.49) or obese (OR=2.94, 95% CI 1.57-5.49) than those in the lowest quintile (Q1). For central obesity, defined by waist circumference, the positive association and the monotonic increase of ORs were preserved when confounding variables were controlled in Model 2 and Model 3 (both *p*-for-trend <0.05).

A weaker significant positive association with the likelihood of being overweight was found for the western pattern scores with confounding variables controlled in all three models (all three *p*-for-trend <0.05) (Table 4). Participants in the highest quintile (Q5) were almost twice as likely to be overweight as those in the lowest quintile (Q1) of urban scores in the fully adjusted Model 3. Western pattern scores showed no clear trend in the likelihood of being obese or centrally obese.

The pastoral dietary pattern, following adjustments, was not associated with being overweight, obese or centrally obese (Table 4).

We also conducted this analysis for central adiposity as defined by WHR. No significant association with the

Table 2. Characteristics of urbanized Tibetan pastoralists by quintiles of dietary pattern scores

	Quintiles of urban pattern score							Quintiles of western pattern score						
	Q1 (Lowest)		Q3		Q5 (Highest)		*p*	Q1 (Lowest)		Q3		Q5 (Highest)		*p*
N	156		156		156			156		156		156		
Age (y) (mean±SD)	44.0	15.3	41.8	12.1	40.2	11.8	0.038*	48.9	12.5	43.0	13.5	33.8	12.3	<0.001***
Women (N, %)	78	50.0	92	59.0	94	60.3	0.14	79	50.6	84	53.8	83	53.2	0.84
Education (N, %)														
No schooling	124	79.5	119	76.3	107	68.6	0.07	139	89.1	118	75.6	91	58.3	<0.001***
<6 y of schooling	16	10.3	10	6.4	17	10.9		8	5.1	17	10.9	17	10.9	
≥6 y of schooling	16	10.3	27	17.3	32	20.5		9	5.8	21	13.5	48	30.8	
Medical insurance (N, %)														
Urban	44	28.2	64	41.0	114	73.1	<0.001***	53	34.0	67	42.9	99	63.5	<0.001***
Rural	109	69.9	86	55.1	40	25.6		99	63.5	87	55.8	52	33.3	
No	3	1.9	6	3.8	2	1.3		4	2.6	2	1.3	5	3.2	
Smoking status (N, %)														
Never	120	76.9	118	75.6	111	71.2	0.48	115	73.7	117	75.0	102	65.4	0.17
Quit	16	10.3	12	7.7	12	7.7		17	10.9	14	9.0	15	9.6	
<5 cigarettes/d	3	1.9	3	1.9	7	4.5		6	3.8	8	5.1	6	3.8	
≥5 cigarettes/d	17	10.9	23	14.7	26	16.7		18	11.5	17	10.9	33	21.2	
Alcohol consumption (N, %)														
Never	125	80.1	126	80.8	123	78.8	0.976	127	81.4	123	78.8	117	75.0	0.112
Abstinence	14	9.0	14	9.0	15	9.6		18	11.5	17	10.9	17	10.9	
<40g/wk	16	10.3	14	9.0	15	9.6		11	7.1	15	9.6	16	10.3	
≥40g/wk	1	0.6	2	1.3	3	1.9		0	0.0	1	0.6	6	3.8	
Physical activity (N, %)														
Light	104	66.7	99	63.5	98	62.8	0.832	108	69.2	103	66.0	104	66.7	0.693
Moderate	24	15.4	26	16.7	31	19.9		29	18.6	31	19.9	25	16.0	
Heavy	28	17.9	31	19.9	27	17.3		19	12.2	22	14.1	27	17.3	

*p<0.05, **p<0.01, ***p<0.001

Table 2. Characteristics of urbanized Tibetan pastoralists by quintiles of dietary pattern scores (cont.)

	Quintiles of pastoral pattern score						
	Q1 (Lowest)		Q3		Q5 (Highest)		*p*
N	156		156		156		
Age (y) (mean±SD)	34.9	12.2	43.2	12.4	43.3	12.6	<0.001***
Women (N, %)	81	51.9	81	51.9	99	63.5	0.06
Education (N, %)							
No schooling	87	55.8	120	76.9	130	83.3	<0.001***
<6 y of schooling	18	11.5	16	10.3	14	9.0	
≥6 y of schooling	51	32.7	20	12.8	12	7.7	
Medical Insurance (N, %)							
Urban	92	59.0	68	43.6	65	41.7	0.002**
Rural	58	37.2	85	54.5	90	57.7	
No	6	3.8	3	1.9	1	0.6	
Smoking status (N, %)							
Never	94	60.3	121	77.6	123	78.8	<0.001***
Quit	10	6.4	14	9.0	12	7.7	
<5 cigarettes/d	10	6.4	3	1.9	5	3.2	
≥5 cigarettes/d	42	26.9	18	11.5	16	10.3	
Alcohol consumption (N, %)							
Never	107	68.6	127	81.4	139	89.1	<0.001***
Abstinence	12	7.7	19	12.2	10	6.4	
<40g/wk	29	18.6	10	6.4	7	4.5	
≥40g/wk	8	5.1	0	0.0	0	0.0	
Physical activity (N, %)							
Light	99	63.5	105	67.3	108	69.2	0.24
Moderate	28	17.9	31	19.9	19	12.2	
Heavy	29	18.6	20	12.8	29	18.6	

*p<0.05, **p<0.01, ***p<0.001.

Table 3. Adjusted means of anthropometric measurements across quintiles of dietary pattern scores among urbanized Tibetan pastoralists

	Quintiles of urban pattern score							Quintiles of western pattern score						
	Q1 (Lowest)		Q3		Q5 (Highest)		*p*	Q1 (Lowest)		Q3		Q5 (Highest)		*p*
N	156		156		156			156		156		156		
BMI (kg/m^2)														
Crude	24.9	0.3	25.2	0.4	26.0	0.4	0.08	26.0	0.4	25.4	0.4	24.9	0.4	0.09
Model 1†	24.7	0.3	25.2	0.3	26.2	0.3	0.005**	25.0	0.4	25.3	0.3	26.0	0.4	0.15
Model 2‡	24.6	0.3	25.2	0.3	26.3	0.3	0.002**	25.0	0.4	25.3	0.3	26.1	0.4	0.12
Model 3§	24.6	0.3	25.2	0.3	26.3	0.3	0.002**	25.0	0.4	25.3	0.3	26.0	0.4	0.14
WC (cm)														
Crude	83.7	0.9	83.9	0.9	84.4	0.9	0.84	85.9	0.9	85.5	0.9	82.2	0.9	0.007**
Model 1†	82.9	0.8	84.0	0.8	85.1	0.8	0.14	83.2	0.9	85.1	0.8	85.2	0.9	0.21
Model 2‡	82.5	0.8	83.9	0.8	85.6	0.8	0.037*	83.1	0.9	85.1	0.8	85.3	0.9	0.17
Model 3§	82.6	0.8	83.9	0.8	85.6	0.8	0.042*	83.2	0.9	85.2	0.8	85.2	0.9	0.20
WHR														
Crude	0.89	0.006	0.89	0.006	0.88	0.005	0.19	0.89	0.006	0.89	0.006	0.87	0.006	0.010*
Model 1†	0.88	0.005	0.89	0.005	0.88	0.005	0.30	0.88	0.006	0.89	0.006	0.88	0.006	0.38
Model 2‡	0.88	0.005	0.89	0.005	0.89	0.006	0.29	0.88	0.006	0.89	0.005	0.89	0.006	0.32
Model 3§	0.88	0.005	0.89	0.005	0.89	0.006	0.30	0.88	0.006	0.89	0.005	0.89	0.006	0.31

	Quintiles of pastoral pattern score						
	Q1 (Lowest)		Q3		Q5 (Highest)		*p*
N	156		156		156		
BMI (kg/m^2)							
Crude	24.6	0.3	25.9	0.4	25.5	0.3	0.021*
Model 1†	25.4	0.3	25.6	0.3	25.1	0.3	0.57
Model 2‡	25.2	0.3	25.7	0.3	25.2	0.3	0.48
Model 3§	25.2	0.3	25.7	0.3	25.2	0.3	0.48
WC (cm)							
Crude	81.5	0.9	86.3	0.9	84.5	0.9	0.001**
Model 1†	83.1	0.9	85.2	0.8	83.9	0.8	0.21
Model 2‡	82.8	0.9	85.5	0.8	84.0	0.8	0.10
Model 3§	82.8	0.9	85.4	0.8	84.0	0.8	0.10
WHR							
Crude	0.87	0.006	0.90	0.006	0.88	0.006	0.006**
Model 1†	0.88	0.006	0.89	0.005	0.88	0.005	0.13
Model 2‡	0.88	0.006	0.89	0.005	0.88	0.005	0.09
Model 3§	0.88	0.006	0.89	0.005	0.88	0.005	0.09

WC: waist circumference; WHR: waist-hip ratio.
Data are presented as mean±SE.
†Model 1: adjusted for gender, age (years)
‡Model 2: additionally adjusted for education (no schooling, <6 y of schooling, ≥6 y of schooling), medical insurance (urban, rural, no insurance), smoking status (never, quit, current <5 cigarettes/day, current ≥5 cigarettes/day), alcohol consumption (never, abstinence, current <40 g/wk, current ≥40g/wk).
§Model 3: further adjusted for self-assessed physical activity (light, moderate, heavy).
*p<0.05, **p<0.01, ***p<0.001.

Table 4. Adjusted odds ratios for increased bodyweight and central obesity across quintiles of dietary pattern scores in urbanized Tibetan pastoralists

	Quintiles of urban pattern score								Quintiles of western pattern score							
	Q1 (Lowest)		Q3		Q5 (Highest)			*p*-trend	Q1 (Lowest)		Q3		Q5 (Highest)			*p*-trend
N	156		156		156				156		156		156			
Overweight †																
Crude	1	0.93	0.59	1.45	1.68	1.06	2.67	0.029*	1	1.03	0.65	1.62	0.81	0.52	1.27	0.36
Model 1§	1	1.01	0.63	1.62	2.11	1.29	3.47	0.003**	1	1.44	0.88	2.35	1.85	1.08	3.17	0.024*
Model 2¶	1	1.05	0.64	1.73	2.58	1.49	4.49	0.001**	1	1.47	0.89	2.42	1.86	1.06	3.25	0.029*
Model 3††	1	1.05	0.64	1.72	2.58	1.48	4.49	0.001**	1	1.46	0.89	2.42	1.81	1.03	3.19	0.037*
Obesity †																
Crude	1	1.56	0.91	2.68	1.83	1.08	3.11	0.026*	1	0.85	0.51	1.40	0.71	0.42	1.19	0.19
Model 1§	1	1.82	1.03	3.22	2.32	1.31	4.09	0.004**	1	1.13	0.66	1.93	1.57	0.86	2.84	0.15
Model 2¶	1	2.01	1.13	3.60	2.95	1.58	5.50	0.001**	1	1.14	0.66	1.97	1.54	0.83	2.89	0.19
Model 3††	1	2.01	1.12	3.60	2.94	1.57	5.49	0.001**	1	1.14	0.66	1.96	1.51	0.80	2.84	0.21
Central obesity ‡																
Crude	1	1.03	0.66	1.61	1.27	0.81	2.00	0.30	1	1.06	0.67	1.68	0.59	0.38	0.93	0.022*
Model 1§	1	1.12	0.68	1.82	1.57	0.96	2.58	0.07	1	1.61	0.97	2.68	1.55	0.90	2.67	0.12
Model 2¶	1	1.17	0.71	1.95	1.98	1.14	3.41	0.015*	1	1.60	0.96	2.69	1.47	0.83	2.59	0.18
Model 3††	1	1.17	0.70	1.94	1.94	1.12	3.36	0.019*	1	1.60	0.95	2.68	1.42	0.80	2.52	0.22

	Quintiles of pastoral pattern score							
	Q1 (Lowest)		Q3		Q5 (Highest)			*p*-trend
N	156		156		156			
Overweight †								
Crude	1	1.41	0.90	2.23	1.30	0.83	2.05	0.25
Model 1	1	0.89	0.54	1.46	0.80	0.49	1.32	0.39
Model 2	1	0.97	0.57	1.63	0.85	0.50	1.43	0.53
Model 3	1	0.95	0.56	1.60	0.85	0.50	1.44	0.54
Obesity †								
Crude	1	1.69	1.00	2.84	1.58	0.94	2.68	0.09
Model 1	1	1.21	0.70	2.10	1.09	0.63	1.91	0.79
Model 2	1	1.38	0.77	2.49	1.23	0.67	2.23	0.58
Model 3	1	1.39	0.77	2.51	1.23	0.67	2.25	0.58
Central obesity ‡								
Crude	1	2.10	1.33	3.31	1.88	1.19	2.95	0.006**
Model 1	1	1.33	0.81	2.19	1.15	0.70	1.90	0.59
Model 2	1	1.58	0.94	2.68	1.35	0.79	2.29	0.30
Model 3	1	1.59	0.94	2.71	1.35	0.80	2.31	0.29

Data are presented as odds ratio and 95% confidence interval. The odds ratio for the participants in the lowest quintile of each dietary score was set as 1.

†Criteria for overweight/obesity classification: overweight, BMI ≥24 kg/m^2; obesity, BMI ≥28 kg/m^2, based on criteria from the Working Group on Obesity in China (WGOC).

‡Central obesity: waist ≥80 cm for women, and ≥85cm for men, based criteria from WGOC.

§Model 1: adjusted for gender, age (years).

¶Model 2: additionally adjusted for education (no schooling, <6 years schooling, ≥6 years schooling), medical insurance (urban, rural, no insurance), smoking (never, quit, current <5 cigarettes/day, current ≥5 cigarettes/day), alcohol (never, abstinence, current <40 g/week, current ≥40 g/week).

††Model 3: further adjusted for physical activity (light, moderate, heavy).

*p<0.05, **p<0.01, ***p<0.001.

three dietary pattern scores was found (data not shown).

We repeated the analyses using the BMI cutoff values from the WHO criteria (overweight as BMI ≥25 kg/m^2, obesity as BMI ≥30 kg/m^2), and found similar results. The urban dietary pattern was positively associated with an increased likelihood of being overweight in all models (all four *p*-for-trend <0.05), and the western dietary pattern was marginally positively associated with increased obesity (*p*-for-trend =0.051 in Model 3) (data not shown).

DISCUSSION

To our knowledge, this study is the first to identify the dietary patterns among Tibetan pastoralists in the process of urbanization and how these dietary patterns relate to overweight or obesity. Three dietary patterns were identified by PCA: urban, western and pastoral. The three dietary patterns aligned with present influences on urbanized Tibetan pastoralists, which may affect their food preferences, choices, and behaviors. Furthermore, the associations between identified dietary patterns and increased body weight were generally in the expected direction.[20] Urban and western dietary patterns were positively associated with increased body weight, however, the effect size differed. No significant associations were found for the pastoral dietary pattern.

Closer examination of the three dietary patterns and the variables associated with them revealed interesting trends. A diverse variety of food was consumed in the urban dietary pattern, including high consumption of vegetables, tubers/roots, and refined carbohydrates (factor loadings ≥0.44), as well as moderate consumption of fresh fruit and pork (factor loadings ≥0.27). These consumed food groups were similar to the combined dietary patterns identified in Chinese urban settings more than a decade ago.[21-24] Applying PCA, Gao et al identified three patterns in north China: (1) high in fruit and milk, (2) high in red meat, and (3) high in refined cereals.[21] Other studies in urban Chinese have also identified three patterns in eastern China: fruit-, vegetable-, and meat-based diets.[22,23] The urban dietary pattern identified among the Tibetan pastoralists included all the important food groups, which belonged to the traditional Chinese diets, demonstrating an influence from mainstream society on dietary intake. Conversely, the diversity of food groups in the identified urban dietary pattern suggests superior access to various foods in urban areas compared with pastoral areas. Thus, the increased access to foods in urban could help to secure local food system.[25]

Counter-intuitively, the urban dietary pattern, which was characterized by high factor loadings in vegetables, was positively associated with being overweight, obese and centrally obese with confounders controlled. Several explanations exist for this. First, the population's diets remained predominantly meat-based, with 90.3% of participants consuming beef/mutton at least once per day. The effect of red meat on the likelihood of developing obesity[26,27] seemingly outweighed the positive effects of vegetables. Given the overall high consumption of beef/mutton, this food group could not be differentiated through PCA among the three identified patterns, leading to relatively low factor loadings in all three patterns (all ≤0.17). Second, without a priori assumption of dietary patterns in PCA, refined carbohydrates identified in current urban dietary pattern, were considered as characteristics of a western diet, which was suggested to be associated with unfavorable plasma biomarkers of obesity,[20] and coronary heart disease.[28] Third, we observed that stir-frying with oil was the primary cooking method for vegetables in the communities studied, and this oil may contribute considerable extraneous calories. The quantity of edible oil used in food preparation was not documented. This should be corrected in further studies. From a public health perspective, the positive relationships between the urban dietary pattern and being overweight and obese indicate that nutrition education and proper guidance are needed among this population, to effectively guide their dietary transition and maximize the benefits of increased food diversity.

The positive association between the urban dietary pattern and central obesity, which was defined by waist circumference, did not hold for central adiposity, which was defined by WHR, despite the similar prevalence of the two conditions. This divergence may be attributed to the different criteria used for central obesity and central adiposity. As suggested by the WHO,[18] cutoff values for both waist circumference and WHR should be ethnicity specific. In the present study, WGOC criteria[17] based on a Chinese population were used for waist circumference, and WHO criteria[18] were applied for WHR, because of a lack of reference criteria for Asian or Chinese populations. Further studies are required to define the ethnicity-specific cutoff values in this unique population based on exposure—disease outcome analysis.

Following adjustments，the second dietary pattern—the western dietary pattern—was positively associated with overweight. This result was in line with studies in other populations that have also found a positive association between a western dietary pattern and obesity[29,30] or other risk factors of cardiovascular diseases.[31,32]

Closer examination of participants' demographics across the quintiles of western dietary pattern scores revealed an inverse association between age and the western dietary pattern score. This result was consistent with global westernized food preferences and the abandonment of traditional diets among the younger generation. Numerous studies have noted the decline of Mediterranean diet among the younger generation.[33-35] Similar situations are visible among indigenous populations[4,5] and other populations in east Asia.[36]

We did not find any significant correlation of the pastoral dietary pattern with obesity. This appears to contradict the prevailing assumption that traditional diets provide health and cultural benefits to indigenous population, which have been undermined by increasing prevalence of western diets and lifestyles.[4,5,37-39] The concept of traditional food varies across different indigenous environments. A well-accepted definition of the traditional food system is all food within a particular culture that is available from local natural resources and culturally accepted.[40] Based on the overall high consumptions of beef and mutton in this population, the traditional pastoral diets in this study also include *tsamba*, Tibetan cheese, buttered tea or milk tea and whole-fat dairy products. This dietary pattern derives from the high-altitude husbandry liveli-

hood and is based on meat and whole-fat dairy products, with plenty of highly energy-dense food. This diet is appropriate in a high-altitude environment, with the intense physical activity and conditions of food scarcity, but it is not necessarily the optimal choice in an urban, settled setting, in which food is abundant, and physical activity is generally low.

Because of the positive correlation measured of urban and western dietary patterns with increased body weight, the health implications of these dietary components must be considered. The addition of healthy food groups, such as vegetables, tuber and roots, diversifies indigenous meat-based diets, and has positive impact for the health of such populations. The consumption of some less healthy food items, such as refined carbohydrates, sugary drinks, and desserts, should be minimized through nutrition education and health promotion programs. Furthermore, the unique health benefits and cultural value of traditional diets have to be emphasized, to improve overall health and well-being.[41] As summarized by Haman, finding effective dietary strategies for dealing with obesity and obesity-related diseases in indigenous populations continues to be a challenge.[38]

A surprising finding from this study was the high prevalence of overweight and obesity among Tibetan pastoralists in urban settled communities. The reported prevalence of overweight and obesity in this population exceeded the 2012 national average (overweight 31.8% vs 30.1%; obesity 26.6% vs 11.9%).[42] The prevalence of both central obesity and adiposity, defined by waist circumference and WHR, respectively, was nearly 60%. We could not directly compare these data with those from previous studies in Tibetan population[6,7,43] because of the differing criteria used to define obesity. Nevertheless, it is likely that the high prevalence of obesity contribute to the high mortality rates due to cardiovascular disease among populations on the Tibetan Plateau, compared with populations in other areas of China.[42] Further randomized control studies are needed to infer the causality of this relationship.

Interpreting the research findings requires various considerations. First, we did not adjust for total energy intake when measuring the association between dietary pattern and obesity, because the portion size data were not gathered during the dietary assessments. However, since overweight or obese people may tend to eat less in hope of decreasing the body weight, such confounding effects would be towards the direction of attenuating the risk estimates. Second, the consumption of some condiments, such as edible oil, and the preparation method of various foods were not included in the dietary assessments. This can be rectified in further studies. Third, although the FFQ used in this study was revised from a FFQ employed in a nationally representative survey, it has not been specifically validated in a Tibetan population. However, the most common validation method is to calibrate the energy and nutrient intakes derived from a FFQ with data from 24-h food recall. Because energy and nutrient intakes were not used in this study, validation of the FFQ was less crucial. Fourth, some arbitrary decisions, such as food groupings, were made during PCA. Fifth, the cross-sectional study design made inference beyond association and the establishment of a causal relationship difficult. The possibility of reverse-causation in cross-sectional study is also an important limitation of this study design. Sixth, participants were not randomly sampled during enrollment, because this would have been impractical in local context; this omission could theoretically cause selection bias. However, the participants in this study comprised more than 25% of the total adult population in the communities studied. Furthermore, the study participants and the total populations had similar age and gender distributions, allowing us to extrapolate our research findings. Because Tibetan pastoralists residing on the Tibetan Plateau are distributed across vast areas with extremely low population density, and the weather conditions on the highland are harsh, acquiring a representative sample is challenging. This study raises awareness of public health issues, such as dietary transition and obesity, experienced by the studied population and ideally will encourage stakeholders to seek a solution.

In conclusion, the three major dietary patterns identified in this study reflect the differing effects of the urban, western and traditional pastoral dietary cultures on urbanized Tibetan pastoralists. Urban and western dietary patterns were positively associated with a greater likelihood of being overweight or obese. Public health and nutrition education programs are required to effectively guide the ongoing dietary transition among this population.

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AUTHOR DISCLOSURES

The authors declare no conflict of interest.

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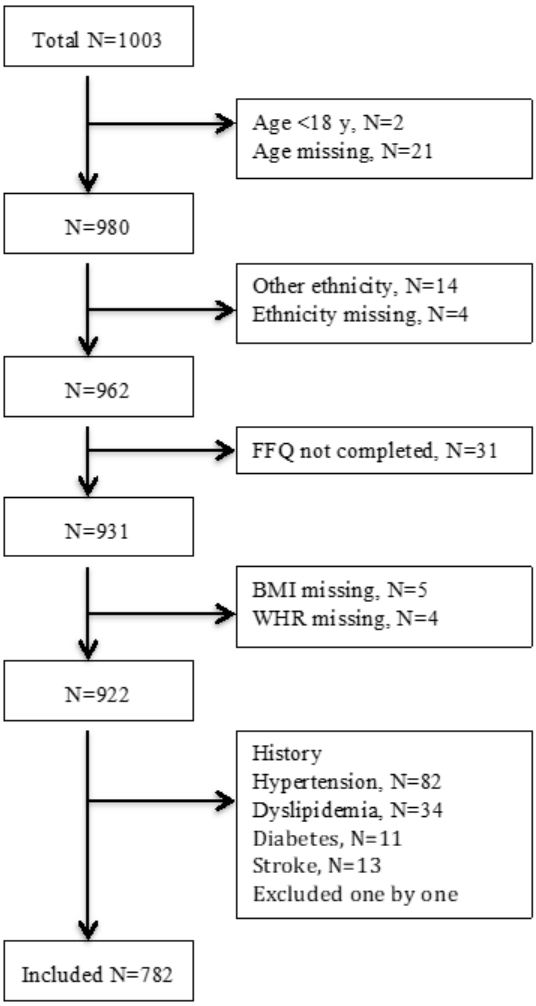

Supplementary figure 1. The flowchart on the inclusion process of participants in the study.

Supplementary table 1. Demographic and lifestyle characteristics of Tibetan pastoralists aged 18 years and above in urban settled communities

	Total N=782		Men N=340		Women N=442		*p* value
Age (Mean, SD)	41.5	13.3	41.7	14.11	41.3	12.7	0.75
Education (N, %)							
No schooling	584	74.7	234	68.8	350	79.2	0.004**
<6 years schooling	71	9.1	36	10.6	35	7.9	
≥6 years schooling	127	16.2	70	20.6	57	12.9	
Insurance (N, %)							
Urban insurance	364	46.5	158	46.5	206	46.6	0.58
Rural insurance	402	51.4	173	50.9	229	51.8	
No insurance	16	2.0	9	2.6	7	1.6	
Smoking (N, %)							
Never	571	73.0	161	47.4	410	92.8	<0.001***
Quit	71	9.1	65	19.1	6	1.4	
<5 cigarettes/day	27	3.5	20	5.9	7	1.6	
≥5 cigarettes/day	113	14.5	94	27.6	19	4.3	
Alcohol (N, %)							
Never	618	79.0	214	62.9	404	91.4	<0.001***
Abstinence	78	10.0	66	19.4	12	2.7	
<40g/week	76	9.7	52	15.3	24	5.4	
≥40g/week	10	1.3	8	2.4	2	0.5	
Physical activity (N, %)							
Light	512	65.5	241	70.9	271	61.3	<0.001***
Moderate	135	17.3	70	20.6	65	14.7	
Heavy	135	17.3	29	8.5	106	24	

**$p<0.01$; ***$p<0.001$.

Supplementary table 2. Overweight, obesity, central obesity and central adiposity among Tibetan pastoralists aged 18 years and above in urban settled communities

	Total N=782		Men N=340		Women N=442		*p*
BMI (kg/m^2) (mean±SD)	25.4	4.5	25.0	4.0	25.8	4.9	0.01*
BMI groups† (N, %)							
Underweight	20	2.6	9	2.6	11	2.5	0.14
Normal weight	305	39.0	135	39.7	170	38.5	
Overweight without obesity	249	31.8	119	35.0	130	29.4	
Obesity	208	26.6	77	22.6	131	29.6	
WC (cm) (mean±SD)	84.4	11.3	86.5	11.2	82.7	11.2	<0.001***
Central obesity‡ (N, %)	461	59.0	190	55.9	271	61.3	0.13
WHR (mean±SD)	0.89	0.07	0.91	0.07	0.87	0.07	<0.001***
Central adiposity§ (N, %)	465	59.5	196	57.6	269	60.9	0.36

WC: waist circumference; WHR: waist-hip-ratio.

†Criteria for overweight/obesity classification: overweight, BMI ≥24 kg/m^2; obesity, BMI ≥28 kg/m^2, based on the criteria from the Working Group on Obesity in China (WGOC).

‡Central obesity: WC ≥80 cm for women, and ≥85 cm for men, based on the criteria from WGOC.

§Central adiposity: WHR ≥0.85 for women, and ≥0.90 for men, based on the Report of a WHO Expert Consultation in 2008.

*$p<0.05$, ***$p<0.001$.