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Analysis of the Epidemiological Characteristics of Different Obesity Metabolic Phenotypes in the Adult Population of Urumqi

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Abstract: This study investigated the distribution of obesity-related metabolic phenotypes among 10,740 adults in Urumqi using multistage stratified random sampling from April 2023 to December 2024. Participants were grouped into four subtypes based on obesity and metabolic health: MHNO (52.7%), MHO (10.9%), MUNO (21.3%), and MUO (15.1%). Statistically significant differences were observed among the groups for all examined characteristics ($P < 0.001$). The MUO group exhibited the highest levels of key metabolic indicators, while the MHNO group had the lowest. The prevalence of MUNO and MUO increased with age, especially among those aged 60 and above. In summary, obesity-related metabolic phenotypes among Urumqi adults vary considerably, with metabolic abnormalities most pronounced among obese and older individuals.

1. Introduction

Overweight and obesity have become one of the most serious global public health issues. According to a report by the World Health Organization (WHO), more than 1 billion adults worldwide were obese in 2022[1]. The obesity problem in China is also showing a continuous upward trend[2]. The Global Obesity Report predicts that by 2025, the proportion of adults in China with a high BMI will reach 41%, and the prevalence of obesity will increase to 9%[3]. Obesity significantly increases the risk of chronic diseases such as cardiovascular and cerebrovascular diseases and type 2 diabetes, thereby compromising physical health[4–6].

Studies indicate that obesity may disrupt the body's energy metabolism homeostasis, exacerbate metabolic burden, and intensify the harmful effects of obesity. However, the heterogeneity of the metabolic phenotype in obesity is complex; some obese individuals exhibit normal metabolism, while some individuals of normal weight display metabolic disorders[7–8]. Consequently, researchers have classified metabolic subtypes of obesity based on obesity and metabolic status into metabolically healthy non-obesity (MHNO), metabolically healthy obesity (MHO), metabolically unhealthy non-obesity (MUNO), and metabolically unhealthy obesity (MUO)[9–10]. Accurately assessing the heterogeneity of the metabolic profile of obesity is of great significance for the

classification, prevention, and control of obesity.

To investigate the epidemiological characteristics of metabolic phenotypes of obesity among the adult population in Urumqi, Northwest China, this study collected relevant data from 10,740 adults in Urumqi between April 2023 and December 2024. By comparing and analyzing the epidemiological features of these metabolic phenotypes, the study aims to provide a scientific basis for the early prevention and control of different metabolic phenotypes of obesity in the adult population of this region.

2. Objects and Methods

2.1 Study Population

From April 2023 to December 2024, a multistage stratified random sampling method was employed. The seven districts and one county currently under the jurisdiction of Urumqi City served as the sampling units. Following a 2:1 urban-to-rural ratio, two districts and one county were randomly selected. Using probability proportional to size sampling, two community health service centers and one township health center were selected, and adults within their jurisdictions who met the inclusion criteria were randomly recruited. Inclusion Criteria: Permanent residents: (1) Resided for ≥6 months; (2) Age ≥18 years; (3) Voluntarily participated in the survey and were able to sign an informed consent form. Exclusion criteria: (1) Pregnant women; individuals with physical or mental disabilities; (2) Individuals with specific medical conditions, such as Alzheimer's disease, malignant tumors, acute infectious diseases, or acquired immunodeficiency syndrome (AIDS); (3) Individuals with obesity caused by medical conditions or medication use; (4) Individuals unable to cooperate with anthropometric measurements or blood sample collection. Based on the inclusion and exclusion criteria, a total of 10,740 study participants were ultimately enrolled.

2.2 Data Collection

A physical examination was conducted in person by a healthcare professional, who measured waist circumference, height, and body weight, and calculated BMI using the formula: BMI = weight (kg) / height ^{2}(m ^{2}). A digital blood pressure monitor was used to measure the patient's systolic blood pressure (SBP) and diastolic blood pressure (DBP) twice, and the average values were recorded. Fasting venous blood is collected by healthcare professionals, measure fasting plasma glucose (FPG), HDL cholesterol, LDL cholesterol, triglycerides (TG), total cholesterol (TCh), blood urea nitrogen (BUN), creatinine (Cr), total bilirubin (TBIL), aspartate aminotransferase (AST), and alanine aminotransferase (ALT).

2.3 Diagnostic Criteria and Classification

Obesity: The BMI classification criteria for the adult population in China are as follows: underweight (BMI < 18.5 kg/m²); normal weight (18.5 ≤ BMI < 24 kg/m²); overweight (24 ≤ BMI < 28 kg/m²); and obese (BMI ≥ 28 kg/m²). Criteria for waist circumference (WC) diagnosis: WC ≥ 90 cm for men or WC ≥ 85 cm for women [11].

Metabolic abnormalities: According to the criteria established by the Third Report of the National Cholesterol Education Program Adult Treatment Panel [12], individuals meeting two or more of the following criteria are defined as having metabolic abnormalities: (1) Elevated blood pressure: SBP ≥130 mmHg and/or DBP ≥85 mmHg, or currently receiving antihypertensive medication; (2) Elevated TG: TG ≥1.70 mmol/L, or currently receiving lipid-lowering medication; (3) Low HDL-C: <1.04 mmol/L in men and <1.29 mmol/L in women; (4) Elevated FPG: FPG ≥

100 mg/dL (≥5.6 mmol/L) and/or currently receiving antidiabetic medication.

Study participants were divided into four groups based on obesity and metabolic abnormalities: (1) MHNO: non-obese and without metabolic abnormalities; (2) MUNO: non-obese but with metabolic abnormalities; (3) MHO: obese but without metabolic abnormalities; (4) MUO: obese and with metabolic abnormalities.

2.4 Statistical Analysis

Data analysis was performed using the R 4.4.3 statistical software. Continuous variables are expressed as x ± s, and categorical variables are expressed as n (%). Intergroup comparisons were performed using the chi-square test and analysis of variance (ANOVA). A *P*-value of <0.05 was considered statistically significant.

3. Result

3.1 Basic Information on the Study Population

Among the 10,740 adults in Urumqi, there were 5,057 men (47.1%) and 5,683 women (52.9%). The mean age was 51.25 ± 16.78 years, and the mean body mass index was (24.67 ± 3.66) kg/m ². There were 5,656 participants with MHNO (52.7%), 1,168 with MHO (10.9%), 2,294 with MUNO (21.3%), and 1,622 with MUO (15.1%). There were statistically significant differences among the four groups in terms of Gender, Age, BMI, WC, Weight, Height, DBP, and SBP ($P < 0.001$) .(see Table 1).

Table 1: Baseline Characteristics of Different Obesity Metabolic Phenotypes in the Adult Population [x ±s/N(%)]

Variables	Overall (N=10740)	MHNO (N=5656)	MHO (N=1168)	MUNO (N=2294)	MUO (N=1622)	*P*
Gender						<0.001
Male	5,057(47.1%)	2,490(44.0%)	533 (45.6%)	1,190(51.9%)	844 (52.0%)	
Female	5,683(52.9%)	3,166(56.0%)	635(54.4%)	1,104(48.1%)	778(48.0%)	
Age	51.25 ±16.78	45.58 ±15.93	54.12 ±15.19	56.04 ±16.36	62.15 ±12.84	<0.001
BMI	24.67 ±3.66	22.98 ±2.57	28.93 ±3.14	23.89 ±2.40	28.61 ±3.36	<0.001
WC	86.75 ±10.64	82.07 ±8.59	96.23 ±9.19	85.74 ±8.30	97.66 ±8.52	<0.001
Weight	67.38 ±12.16	63.19 ±9.60	78.59 ±11.88	64.87 ±9.82	77.47 ±12.57	<0.001
Height	165.06 ±8.80	165.60 ±8.52	164.59 ±9.04	164.50 ±8.89	164.33 ±9.31	<0.001
DBP	79.07 ±12.01	75.89 ±11.44	77.70 ±10.84	84.38 ±11.83	83.66 ±10.85	<0.001
SBP	127.62 ±18.32	120.68 ±15.50	127.33 ±17.34	136.04 ±18.24	140.11 ±16.56	<0.001

3.2 Differences in the Age and Sex Distribution of Different Obesity Metabolic Phenotypes in the Adult Population

In both male and female populations, the distribution of metabolic phenotypes associated with obesity changes with increasing age. The proportion of MHNO decreases with age, while the proportions of MUNO and MUO both increase with age; the increase in MHO is relatively small. Furthermore, women generally have better metabolic health than men, and the overall prevalence of obesity is higher among men than among women. The distribution trends of each metabolic phenotype across different age groups are all statistically significant ($P < 0.01$) .(see Table 2).

Table 2: Age and Sex Distribution of Different Obesity Metabolic Phenotypes in the Adult Population [N(%)]

Age	Male (N=5057)					Female (N=5683)				
	N	MHNO (N=2490)	MUNO (N=1190)	MHO (N=533)	MUO (N=844)	N	MHNO (N=3166)	MUNO (N=1104)	MHO (N=635)	MUO (N=778)
18~29	550	410 (74.6%)	82 (14.9%)	37 (6.7%)	21 (3.8%)	645	539 (83.6%)	61 (9.5%)	37 (5.7%)	8 (1.2%)
30~39	759	491 (64.7%)	143 (18.8%)	79 (10.4%)	46 (6.1%)	901	692 (76.8%)	117 (13%)	71 (7.9%)	21 (2.3%)
40~49	950	549 (57.8%)	200 (21.1%)	97 (10.2%)	104 (10.9%)	1058	730 (69%)	167 (15.8%)	101 (9.5%)	60 (5.7%)
50~59	1114	521 (46.7%)	278 (25.0%)	117 (10.5%)	198 (17.8%)	1251	654 (52.3%)	265 (21.2%)	187 (14.9%)	145 (11.6%)
60~69	876	302 (34.5%)	217 (24.8%)	107 (12.2%)	250 (28.5%)	974	326 (33.5%)	235 (24.1%)	140 (14.4%)	273 (28%)
≥70	808	217 (26.9%)	270 (33.4%)	96 (11.9%)	225 (27.8%)	854	225 (26.4%)	259 (30.3%)	99 (11.6%)	271 (31.7%)
χ^2 value		479.013	73.747	9.228	291.490		910.362	152.460	34.687	575.595
P value		<0.001	<0.001	<0.01	<0.001		<0.001	<0.001	<0.001	<0.001

3.3 Comparison of Metabolic Markers across Different Obesity Metabolic Phenotypes in Adults

There were significant differences among the four groups in terms of HDL-C, LDL-C, TG, TCh, BUN, Cr, TBIL, AST, ALT, FBG levels ($P < 0.001$). Specifically, the MUO group had the highest levels of all these markers, the MHNO group had the lowest, and the MHO and MUNO groups fell between the two. (see Table 3).

Table 3: Comparison of Metabolic Markers across Different Obesity Metabolic Phenotypes in the Adult Population ($\bar{x} \pm s$)

Variables	Overall (N=10740)	MHNO (N=5656)	MHO (N=1168)	MUNO (N=2294)	MUO (N=1622)	*P*
HDL-C	1.46±0.45	1.48±0.43	1.61±0.45	1.32±0.40	1.44±0.50	<0.001
LDL-C	2.04±0.80	1.97±0.72	2.18±0.84	1.98±0.80	2.24±0.95	<0.001
TG	1.36±0.83	1.13±0.51	1.22±0.56	1.64±0.97	1.90±1.20	<0.001
TCh	4.30±1.21	4.14±1.26	4.41±1.04	4.41±1.16	4.67±1.11	<0.001
BUN	5.17±3.91	5.11±4.28	4.97±2.67	5.19±3.74	5.49±3.50	<0.001
Cr	65.84±16.54	63.59±15.13	67.04±15.71	66.11±17.07	72.42±19.06	<0.001
TBIL	12.03±6.05	11.76±5.91	12.39±6.11	11.88±6.48	12.93±5.80	<0.001
AST	22.08±9.42	21.03±8.95	23.11±10.19	22.66±9.82	24.19±9.40	<0.001
ALT	21.63±13.63	19.93±11.91	23.82±16.68	22.15±13.94	25.22±15.27	<0.001
FBG	5.30±2.49	4.90±2.50	5.44±2.99	5.61±2.24	6.19±2.04	<0.001

4. Discussion

Based on an analysis of a large-scale adult population dataset from Urumqi, this study examined the epidemiological characteristics of different obesity metabolic phenotypes. The results showed that the MHNO phenotype had the highest prevalence, accounting for 52.7%. The MHO, MUNO, and MUO phenotypes accounted for 10.9%, 21.3%, and 15.1%, respectively. These findings differ

somewhat from those of a study conducted among urban adults in Shaanxi Province, primarily in that the proportions of MHO and MUO groups were relatively higher in this study[13]. This discrepancy may be primarily attributed to differences in the criteria used to define obesity. Previous studies have predominantly used BMI as the indicator for obesity, whereas this study adopted the latest guidelines to incorporate waist circumference as a core criterion for determining obesity[14]. As a direct measure of central obesity, waist circumference more accurately reflects the degree of visceral fat accumulation, and central obesity is particularly closely associated with metabolic disorders[15]. Therefore, the use of waist circumference criteria may identify more obese individuals characterized by abdominal fat accumulation, leading to the higher proportions of MHO and MUO groups in this study.

From a gender perspective, the prevalence of obesity was higher in men than in women, consistent with the findings of Li Yuan [16]. In terms of age distribution, the proportion of MHNO decreased with increasing age in both men and women, while the proportions of MUNO and MUO increased. Notably, the proportion of the MUO group increased significantly in individuals aged 60 years and older, suggesting that advancing age is a key factor contributing to the shift toward an unhealthy metabolic state.

Regarding metabolic indicators, this study found that TG, FBG, SBP, and DBP levels in the MUNO and MUO groups were significantly higher than those in the MHNO group, while HDL-C levels were significantly lower. This is consistent with the findings of Su[17] ,and further confirms the significant impact of metabolic abnormalities on lipid profiles, blood glucose, and blood pressure. Regarding liver and kidney function indicators, the levels of Cr, AST, and ALT in the MUO group were significantly higher than those in the other three groups, suggesting that the metabolically unhealthy obesity phenotype is closely associated with liver and kidney dysfunction. This is consistent with previous studies suggesting that obesity combined with metabolic disorders can exacerbate damage to target organs [18–19]. Although ALT levels in the MHO group were lower than those in the MUO group, they remained higher than those in the MHNO group, suggesting that even in a metabolically healthy state, obesity itself may still exert a certain influence on liver function.

5. Conclusions

This study found, through cross-sectional analysis, that there is significant metabolic heterogeneity among the adult population in Urumqi. While a group of individuals who are obese but metabolically healthy does exist, their proportion is relatively low, and there are significant differences in age distribution and metabolic indicators among the various phenotypes. Future efforts should focus on strengthening the dynamic monitoring of different obesity-metabolic phenotypes, particularly through early intervention among middle-aged and older adults, to delay the transition from metabolic health to an unhealthy state.

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