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The prevalence of obesity and the relationship between obesity indicators and chronic diseases in Northern Shaanxi, China

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Abstract

Introduction: Obesity not only affects human health but also is an important risk factor for a variety of chronic diseases. Therefore, it is particularly important to analyse the epidemic trend of obesity and actively carry out the prevention and control of obesity in the population.
Material and methods: A total of 4565 adults were selected by multi-stage stratified random sampling in Shenmu, Shaanxi Province, China. Univariate analysis was used to explore the epidemic characteristics of obesity in this region. Multivariate logistic regression was used to analyse the relationship between obesity and chronic diseases. Finally, the prediction efficiency of different obesity indexes was analysed by drawing receiver operator characteristic curves (ROC). All statistical analysis was completed by SPSS 26.0 software.
Results: The prevalence rates of overweight, obesity, and central obesity were 39.9%, 18.2%, and 48.0%, respectively. After adjusting for other confounding factors, multivariate logistic regression analysis showed that overweight and obesity were risk factors for hypertension, dyslipidaemia, and hyperuricaemia. Central obesity is a risk factor for dyslipidaemia and hyperuricaemia. High level of waist-to-height ratio (WHtR) was a risk factor for dyslipidaemia and hyperuricaemia ($p < 0.05$). Obesity-related indicators: body mass index (BMI), waist circumference (WC), and WHtR, are strongly correlated with the increased risk of chronic diseases in northern Shaanxi, China. The optimal BMI cut-off values for predicting hypertension, dyslipidaemia, and hyperuricaemia were 24.27, 24.04, and 25.54, respectively. The optimal WC cut-off values for predicting dyslipidaemia and hyperuricaemia were 84.5 and 90.5, and WHtR cut-off values were 0.52 and 0.54, respectively.
Conclusion: The problem of overweight, obesity, and central obesity in adults is serious in northern Shaanxi, China. Obesity of all types will increase the risk of chronic diseases. Therefore, a variety of preventive and therapeutic measures should be adopted to curb obesity and reduce the incidence of related chronic diseases. **(Endokrynol Pol 2024; 75 (1): 71–82)**

Key words: *obesity; BMI; WC; chronic diseases; Han population from Northern Shaanxi, China*

Introduction

Obesity refers to the disorder of energy balance caused by long-term energy intake exceeding consumption, resulting in the storage of body energy in the form of fat, and the accumulation of fat will damage health [1]. With the development of social economy, obesity has become a common disease, and the number of obese people is gradually increasing, which will lead to some social and economic side effects [2–5]. Obesity is increasingly concerned. A number of studies have investigated the epidemiological characteristics of obesity, and the results of these studies show significant regional differences in the prevalence of obesity. Therefore, it is necessary to carry out epidemiological investigations of obesity for people in specific regions.

According to the different storage sites of fat in the body, obesity is divided into systemic (peripheral) obesity and central (abdominal) obesity [6, 7]. The distribution of fat and the overall health status of fat in obese people have a great impact on the risk of disease [8]. Body mass index (BMI) is considered to be one of the important indicators of systemic obesity in the Chinese population, while central obesity is mainly assessed by WC (waist circumference) [9]. Obesity and/or central obesity are closely related to various chronic diseases

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or their risk factors [10–12]. However, it is important to note that the different anthropometric parameters used to define obesity do not accurately reflect the body composition (percentage of adipose tissue) associated with the risk of comorbidities [8, 13]. In the analysis of the correlation between obesity and disease in Asian populations, BMI and WC are usually used as indicators representing the degree of obesity [14, 15]. Although the application of the waist-to-height ratio (WHtR) is not as widely used as BMI and WC, studies showed that WHtR was more effective than BMI and WC in predicting diabetes and hypertension in the Bangladeshi population [16]. Another study suggested that locally abnormal fat distribution may be a better predictor of cardiovascular disease risk in people with abdominal or central obesity [17]. These studies suggest that it is necessary to include BMI, WC, and WHtR in the analysis of the relationship between obesity and chronic diseases, which will help identify the best indicators for predicting the risk of obesity or chronic disease.

Shenmu city is located in the northern part of Shaanxi Province in China. In recent years, the rapid economic development of Shenmu city has greatly improved the living standard, and thus the incidence of chronic diseases has increased. At present, there is no study on the epidemiological characteristics of obesity in northern Shaanxi, China, especially in Shenmu. This study intends to investigate the distribution characteristics of obesity-related indicators and the relationship between them and chronic diseases. This study will provide basic data and scientific guidance for the development of prevention and control strategies for obesity and common chronic diseases.

Material and methods

Survey subject

From August to December 2019, we selected adults from 2 communities (Linzhou Community and Yingbin Road Community) and 4 towns (Jinjie town, Daliuta town, Hejiachuan town, and Langanbao town) in Shenmu city, Shaanxi province, as the subjects of this study. In this study, a total of 4706 adults participated in the survey by multi-stage stratified random sampling. After excluding the data missing or unqualified people, finally 4565 people were included in this study. This research was conducted after obtaining the informed consent of all the subjects. At the same time, this study was approved by the Ethics Committee of Shenmu Hospital (No. sm004).

Data collecting

The data of this study were collected by professionally trained investigators. The data collection of this study was mainly completed by questionnaire survey, physical examination, or laboratory testing. (1) Questionnaire survey: we developed an epidemiological questionnaire after consulting the literature and consulting experts; the main contents of the questionnaire include gender, age, educational level, marital status, smoking/drinking status, and past medical history. (2) Physical examinations were obtained through on-site measurements of uniform measuring equipment. Physical examination included height, weight, waist circumference, systolic blood pressure, diastolic blood pressure; (3) The main contents of laboratory tests include total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), uric acid (UC), and fasting plasma glucose (FPG).

Diagnostic standard

(1) Overweight, obesity, and central obesity: BMI < 18.5 kg/m^2 was defined as underweight, 18.5 kg/m^2 ≤ BMI < 24 kg/m^2 as normal weight, 24 kg/m^2 ≤ BMI < 28 kg/m^2 as overweight, and BMI ≥ 28 kg/m^2 as obesity [18]. Male waist circumference ≥ 90 cm or female waist circumference ≥ 85 cm were defined as central obesity [19]; WHtR > 0.5 can be defined as central obesity, which can indicate an increased health risk [20].

(2) Hypertension: systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg is defined as hypertension, when taking antihypertensive drugs or not using antihypertensive drugs [21].

(3) Diabetes: fasting blood glucose ≥ 7.0 mmol/L or currently taking hypoglycaemic drugs/insulin is defined as diabetic [22].

(4) Dyslipidaemia: dyslipidaemia is defined if one or more of the following conditions occur: total cholesterol (TC) ≥ 5.2 mmol/L, triglyceride (TG) ≥1.7 mmol/L, and high-density lipoprotein-cholesterol (HDL-C) < 1.0 mmol/L [23].

(5) Hyperuricaemia: fasting blood uric acid >420 μmol/L in adults is defined as hyperuricaemia [24].

Statistical analysis of data

The measurement data were described by mean ± standard deviation (SD). Statistical description of the adoption rate or constituent ratio of counting data. The detection rates and epidemiological characteristics of overweight, obesity, and central obesity were analysed by χ^2 test. Multivariate logistic regression analysis was used to analyse the relationship between obesity and hypertension, diabetes, dyslipidaemia, and hyperuricaemia. Finally, with BMI, WC, and WHtR as test variables and chronic disease aggregation as state variables, a receiver operator characteristic curve (ROC) was drawn to analyse the prediction efficiency of different obesity indicators. $p < 0.05$ was considered statistically significant.

Results

Survey of research objects

General characteristics

A total of 4565 participants were included in this study, including 1826 (40 %) males and 2739 (60%) females. Ages ranged from 18 to 82 years, with an average of 47.48 ± 11.27 years. 50–59 years old accounted for the highest proportion, accounting for 29.3%, and 18–29 years old accounted for the lowest proportion, at 6.5%. About the distribution of educational level, primary school and below accounted for the highest proportion, at 50.5%, and high school and secondary school accounted for the lowest proportion, at 11.3 %. The total number of non-smokers in the study population was 2892 (63.4%), but the proportion of male smokers was higher than that of non-smokers, with a total of 1410 (77.2%), while the number of female smokers was only 263 (9.6%). The average WC for females was 83.09 ± 9.78 cm and the average WHtR was 0.52 ± 0.06 cm, while the average WC for males was 90.00 ± 9.55 cm and the average WHtR was 0.53± 0.06 cm. The indicator data for participants are detailed in Table 1.

Epidemiological characteristics of obesity

Distribution characteristics of overweight, obesity, and central obesity: the average BMI of the population in this region was 24.89 ± 3.53 kg/m², and the average BMI of males and females was 25.34 ± 3.53 kg/m² and 24.59 ± 3.51 kg/m², respectively (Tab. 1). The detection rate of obesity in this region is shown in Table 2. The proportion of overweight people was 39.9%, and that of obese people was 18.2%. The proportion of central obesity was 48.0%, and the proportion of central obesity in males and females was 54.5% and 43.7%, respectively.

In this study, obesity was classified according to BMI and WC, and the epidemiological characteristics of obesity in Shenmu city were investigated. The results showed that the detection rate of women is higher than that of men regardless of the type of obesity. In both male and female investigated populations,

Table 1. *Information of characteristics for the investigated population*

Characteristics	Total	Male	Female
Number	4565	1826 (40%）	2739 (60%）
Age (years)			
Mean ± SD	47.48 ± 11.27	48.62 ± 11.65	46.73 ± 10.95
18–29	295 (6.5%)	120 (6.6%)	175 (6.4%)
30–39	908 (19.9%)	319 (17.5%)	589 (21.5%)
40–49	1280 (28%)	471 (25.8%)	809 (29.5%)
50–59	1336 (29.3%)	524 (28.7%)	812 (29.6%)
≥ 60	746 (16.3%)	392 (21.5%)	354 (12.9%)
Education level			
A	2307 (50.5%)	599 (32.8%)	1708 (62.4%)
B	1177 (25.8%)	716 (39.2%)	461 (16.8%)
C	518 (11.3%)	272 (14.9%)	246 (9%)
D	563 (12.3%)	239 (13.1%)	324 (11.8%)
Smoking			
No	2892 (63.4%)	416 (22.8%)	2476 (90.4%)
Yes	1673 (36.6%)	1410 (77.2%)	263 (9.6%)
Height [mean ± SD]	163.07 ± 7.76	168.85 ± 6.56	159.22 ± 5.9
Weight [mean ± SD]	66.32 ± 11.23	72.32 ± 11.33	62.32 ± 9.21
BMI [mean ± SD]	24.89 ± 3.53	25.34 ± 3.53	24.59 ± 3.51
Obese degree			
Normal	1804 (39.5%)	625 (34.2%)	1179 (43%)
Underweight	110 (2.4%)	35 (1.9%)	75 (2.7%)
Overweight	1820 (39.9%)	751 (41.1%)	1069 (39%)
Obesity	831 (18.2%)	415 (22.7%)	416 (15.2%)
WC [mean ± SD]	85.86 ± 10.26	90 ± 9.55	83.09 ± 9.78
Central obesity			
No	2373 (52%)	830 (45.5%)	1543 (56.3%)
Yes	2192 (48%)	996 (54.5%)	1196 (43.7%)
WhtR			
Mean ± SD	0.52 ± 0.06	0.53±0.06	0.52 ± 0.06
< P25	341 (18.7%)	803 (29.3%)	1144 (25.1%)
P25 ≤ WhtR < P50	461 (25.2%)	666 (24.3%)	1127 (24.7%)
P50 ≤ WhtR < P75	515 (28.2%)	641 (23.4%)	1156 (25.3%)
≥ P75	509 (27.9%)	629 (23%)	1138 (24.9%)

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Table 1. *Information of characteristics for the investigated population*

Characteristics	Total	Male	Female
Systolic pressure Mean ± SD	127.4 ± 18.76	128.99 ± 17.65	126.33 ± 19.4
Diastolic pressure Mean ± SD	80.15 ± 12.31	82.08 ± 12.09	78.86 ± 12.29
Hypertension			
No	3933 (86.2%)	1564 (85.7%)	2369 (86.5%)
Yes	632 (13.8%)	262 (14.3%)	370 (13.5%)
Fasting plasma glucose (FPG)	4.97 ± 1.32	5.1 ± 1.47	4.88 ± 1.2
Diabetes			
No	4370 (95.7%)	1721 (94.2%)	2649 (96.7%)
Yes	195 (4.3%)	105 (5.8%)	90 (3.3%)
TC Mean ± SD	4.54 ± 0.93	4.61 ± 0.94	4.49 ± 0.91
TG Mean ± SD	1.66 ± 1.3	1.84 ± 1.54	1.54 ± 1.09
HDL-C Mean ± SD	1.37 ± 0.49	1.28 ± 0.47	1.42 ± 0.49
Dyslipidaemia			
No	2140 (46.9%)	719 (39.4%)	1421 (51.9%)
Yes	2425 (53.1%)	1107 (60.6%)	1318 (48.1%)
UA [mean ± SD]	287.97 ± 81.84	336.56 ± 81.47	255.57 ± 64.15
Hyperuricaemia			
No	4248 (93.1%)	1557 (85.3%)	2691 (98.2%)
Yes	317 (6.9%)	269 (14.7%)	48 (1.8%)

TC — total cholesterol; TG — triglyceride; HDL-C — high-density lipoprotein-cholesterol; UA — uric acid; BMI — body mass index; WC — waist circumference; WhtR — waist-to-height ratio. Education level: primary school or lower (A), junior middle school (B), senior middle school and secondary specialized school (C), college or higher (D). Obese degree: underweight (BMI < 18.5), normal (18.5 ≤ BMI < 24), overweight (24 ≤ BMI < 28), obesity (BMI ≥ 28). Central obesity: male waist circumference ≥ 90 cm or female waist circumference ≥ 80 cm

central obesity has the highest detection rate (Tab. 2). Figure 1 shows the histogram of obesity distribution by gender. As shown in Table 2, the male obesity rate (overweight: 41.1%; obesity: 22.7%; central obesity: 54.5%) is significantly higher than the female obesity rate (overweight: 39.0%; obesity: 15.2%; central obesity: 43.7%) ($p < 0.001$). As shown in Figure 2, the detection rates of overweight and obesity first increased and then decreased with age. The detection rate of central obesity has been on the rise, and the detection rates of overweight, obesity, and central obesity all grew fastest in the 40–49 years age group ($p < 0.001$). With the increase of education level, the detection rate of overweight, obesity, and central obesity decreased. The prevalence of overweight, obesity, and central obesity in the married population was significantly higher than that in the unmarried, divorced, and widowed population ($p < 0.001$). The prevalence of overweight, obesity, and central obesity in smokers was higher than that in non-smokers ($p < 0.001$). All the above results are shown in Table 2.

Risk factors of obesity

Multivariate logistic regression analysis was used to explore the risk factors of obesity. The results show that senior middle school and secondary specialized school have no significant influence on overweight. The age group of 30–39 years has no significant influence on obesity. In addition to the above-mentioned, gender, age, education level, marriage status, and smoking status have significant influences on different types of obesity. Specifically, females (reference: male), people with a high level of education (reference: primary school or lower), unmarried /divorced/widowed people (reference: married), and smokers (reference: non-smoking) are protection factors (odds ratio [OR] < 1, $p < 0.05$) for overweight, obesity, and central obesity. Most groups with older age were risk factors for overweight, obesity,

Table 2. *Univariate analysis for influencing factors of obesity indicators*

Variation	Total				Male				Female			
	N	Overweight	Obesity	Central obesity	N	Overweight	Obesity	Central obesity	N	Overweight	Obesity	Central obesity
Total	4565	1820 (39.9)	831 (18.2)	2192 (48.0)	1826	751 (41.1)	415 (22.7)	996 (54.5)	2739	1069 (39)	416 (15.2)	1196 (43.7)
Age												
18~29	295	65 (22)	40 (13.6)	65 (22.0)	120	42 (35)	24 (20)	42 (35)	175	23 (13.1)	16 (9.1)	23 (13.1)
30~39	908	293 (32.3)	152 (16.7)	324 (35.7)	319	118 (37)	87 (27.3)	173 (54.2)	589	175 (29.7)	65 (11)	151 (25.6)
40~49	1280	584 (45.6)	251 (19.6)	637 (49.8)	471	219 (46.5)	128 (27.2)	302 (64.1)	809	365 (45.1)	123 (15.2)	335 (41.4)
50~59	1336	588 (44)	252 (18.9)	748 (56.0)	524	226 (43.1)	111 (21.2)	298 (56.9)	812	362 (44.6)	141 (17.4)	450 (55.4)
≥ 60	746	290 (38.9)	136 (18.2)	418 (56.0)	392	146 (37.2)	65 (16.6)	181 (46.2)	354	144 (40.7)	71 (20.1)	237 (66.9)
χ^2		99.03	31.38	189.91		26.00	33.56	48.14		110.09	49.08	269.40
p		< 0.001	< 0.001	< 0.001		< 0.001	< 0.001	< 0.001		< 0.001	< 0.001	< 0.001
Education level												
A	2307	971 (42.1)	439 (19)	1250 (54.2)	599	229 (38.2)	139 (23.2)	330 (55.1)	1708	742 (43.4)	300 (17.6)	920 (53.9)
B	1177	476 (40.4)	215 (18.3)	554 (47.1)	716	307 (42.9)	156 (21.8)	399 (55.7)	461	169 (36.7)	59 (12.8)	155 (33.6)
C	518	214 (41.3)	87 (16.8)	221 (42.7)	272	124 (45.6)	56 (20.6)	151 (55.5)	246	90 (36.6)	31 (12.6)	70 (28.5)
D	563	159 (28.2)	90 (16)	167 (29.7)	239	91 (38.1)	64 (26.8)	116 (48.5)	324	68 (21)	26 (8)	51 (15.7)
χ^2		41.24	12.31	117.50		5.95	1.83	4.06		80.29	48.52	216.97
p		< 0.001	0.006	< 0.001		0.114	0.608	0.255		< 0.001	< 0.001	< 0.001
Marriage												
Yes	4265	1731 (40.6)	796 (18.7)	2095 (49.1)	1713	717 (41.9)	397 (23.2)	957 (55.9)	2552	1014 (39.7)	399 (15.6)	1138 (44.6)
No	300	89 (29.7)	35 (11.7)	97 (32.3)	113	34 (30.1)	18 (15.9)	39 (34.5)	187	55 (29.4)	17 (9.1)	58 (31)
$\chi 2$		15.33	13.40	31.65		9.00	6.73	19.50		6.86	6.92	13.06
p		< 0.001	< 0.001	< 0.001		0.003	0.009	< 0.001		0.009	0.009	< 0.001
Smoking												
No	2892	1142 (39.5)	482 (16.7)	1283 (44.4)	416	179 (43)	107 (25.7)	229 (55)	2476	963 (38.9)	375 (15.1)	1054 (42.6)
Yes	1673	678 (40.5)	349 (20.9)	909 (54.3)	1410	572 (40.6)	308 (21.8)	767 (54.4)	263	106 (40.3)	41 (15.6)	142 (54)
χ^2		4.23	15.78	42.21		4.31	6.33	0.06		0.37	0.18	12.61
p		0.040	< 0.001	< 0.001		0.038	0.012	0.815		0.542	0.675	< 0.001

N — number. Obese degree: underweight (BMI < 18.5), normal (18.5 ≤ BMI < 24), overweight (24 ≤ BMI < 28), obesity (BMI ≥ 28). Central obesity: male waist circumference ≥ 90 cm or female waist circumference ≥ 80 cm. Education level: primary school or lower (A), junior middle school (B), senior middle school and secondary specialized school (C), college or higher (D). Marriage: married (Yes), unmarried/divorced/widowed (No). $p < 0.05$ and text bold represent statistically significant

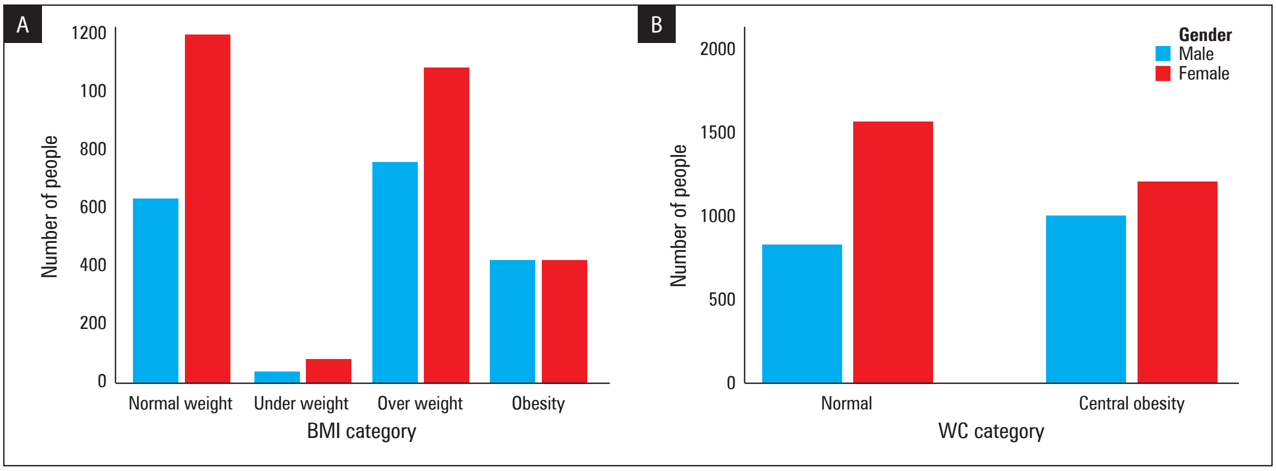

Figure 1. *Gender (**A**) and obesity (**B**) detection rate. BMI — body mass index; WC — waist circumference*

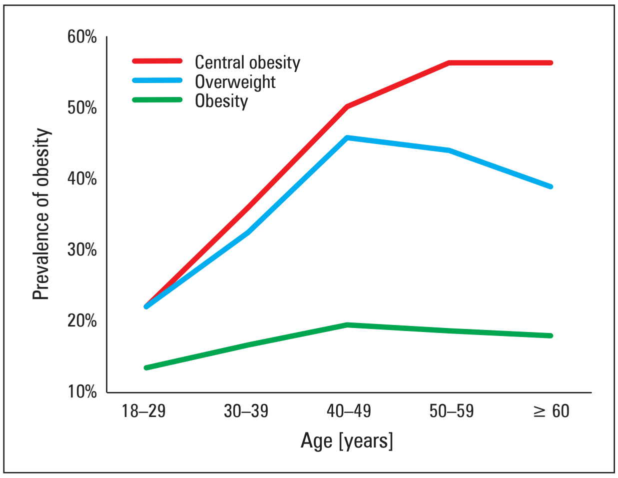

Figure 2. *Age and obesity detection rate*

and central obesity compared with those aged 18–29 years (OR > 1, p < 0.05). The specific results can be seen in Table 3.

Association between obesity and chronic disease

Among the investigated population, 632 (13.8%) suffered from hypertension, 195 (4.3%) suffered from diabetes, 2425 (53.1%) suffered from dyslipidaemia, and 317 (6.9%) suffered from hyperuricaemia (Tab. 1). We also explored the influencing factors of chronic diseases by univariate analysis. The results showed that some influencing factors were not only risk factors for chronic diseases but also interfered with obesity-related indicators, thus affecting chronic diseases (Supplementary File — Tab. S1).

Multivariate logistic regression was used to analyse the relationship between obesity-related indicators and the prevalence of chronic diseases after adjusting these confounding factors. Table 4 shows that after adjusting for gender, age, education level, marital status, smoking, and WC, overweight and obesity are risk factors for hypertension (overweight: OR = 1.55, *p* = 0.001; obesity: OR = 1.51, p = 0.021), lipid abnormality (overweight: OR = 1.59, p < 0.001; obesity: OR = 1.74, p < 0.001), and hyperuricaemia (overweight: OR = 1.81, p = 0.005; obesity: OR = 2.15, p = 0.003), while obesity is a protective factor for diabetes (OR = 0.47, p = 0.011). For WC, after adjusting for other confounders and BMI, central obesity risk factors for lipid abnormality (OR = 1.36, p < 0.001) and hyperuricaemia (OR = 2.16, p = 0.001). For WHtR, after adjusting for other confounders, WC, and BMI, WHtR values in P50 <P75 is a risk factor for lipid abnormality (OR = 1.48, p = 0.007) and hyperuricaemia (OR = 2.16, p = 0.032).

Accuracy and efficacy of different obesity indicators in predicting chronic diseases

With BMI, WC, and WHtR as test variables and chronic disease cluster as a state variable, ROC curves of 3 obesity-related indicators for predicting chronic diseases were drawn and their sensitivity was calculated (Fig. 3, Tab. 5). Table 5 summarizes the sensitivity of BMI, WC, and WHtR in predicting hypertension (72.8%, 72.5%, and 76.9%, respectively), diabetes (87.2%, 81.5%, and 82.1%, respectively), dyslipidaemia (70.8% and 70.8%, respectively), and hyperuricaemia (66.2%, 65.9%, and 69.4%, respectively). According to the principle of maximum Youden index, the optimal cut-off values of BMI, WC, and WHtR for predicting hypertension (24.27, 85.5, and 0.52, respectively), diabetes (22.74, 84.5, and 0.52, respectively), dyslipidaemia (24.04, 84.5, and 0.52, respectively), and hyperuricaemia (25.54, 90.5, and 0.54, respectively) were obtained.

In addition, we also compared the predictive efficacy of different obesity indexes for chronic diseases in the Shenmu population for male population and female population. The detailed results are shown in Table 5.

Table 3. *Multivariate logistic regression analysis for risk factors of obesity*

Variation	BMI							WC			
	Normal	Overweight			Obesity			Non-central obesity	Central obesity		
		N	OR (95% CI)	p	N	OR (95% CI)	p		N	OR (95% CI)	p
Sex											
Male	625	751	1		415	1		830	996	1	
Female	1179	1069	0.79 (0.69–0.91)	0.001	416	0.55 (0.46–0.65)	0.001	1543	1196	0.68 (0.60–0.77)	0.001
Age											
18~29	153	65	1		40	1		230	65	1	
30~39	438	293	1.55 (1.06–2.26)	0.023	152	1.55 (0.98–2.46)	0.061	584	324	1.67 (1.19–2.35)	0.003
40~49	433	584	3.73 (2.33–5.97)	< 0.001	251	3.50 (1.99–6.18)	< 0.001	643	637	3.78 (2.48–5.75)	< 0.001
50~59	475	588	3.96 (2.27–6.94)	< 0.001	252	4.16 (2.11–8.20)	< 0.001	588	748	5.95 (3.60–9.82)	< 0.001
≥ 60	305	290	3.37 (1.74–6.52)	< 0.001	136	4.13 (1.86–9.18)	0.001	328	418	6.85 (3.80–12.35)	< 0.001
Education level											
A	860	971	1		439	1		1057	1250	1	
B	465	476	0.83 (0.71–0.97)	0.019	215	0.70 (0.57–0.85)	< 0.001	623	554	0.60 (0.53–0.70)	< 0.001
C	198	214	0.90 (0.73–1.12)	0.340	87	0.71 (0.54–0.94)	0.015	297	221	0.54 (0.44–0.65)	< 0.001
D	281	159	0.54 (0.44–0.66)	< 0.001	90	0.54 (0.42–0.69)	< 0.001	396	167	0.38 (0.32–0.46)	< 0.001
Marriage											
Yes	1658	1731	1		796	1		2170	2095	1	
No	146	89	0.60 (0.46–0.78)	< 0.001	35	0.45 (0.30–0.65)	< 0.001	203	97	0.50 (0.39–0.64)	< 0.001
Smoking											
No	1191	1142	1		482	1		1609	1283	1	
Yes	613	678	0.71 (0.59–0.86)	< 0.001	349	0.66 (0.53–0.84)	< 0.001	764	909	0.74 (0.63–0.88)	< 0.001

BMI — body mass index; WC — waist circumference; N — number; OR — odds ratio; CI — confidence interval. Education level: primary school or lower (A), junior middle school (B), senior middle school and secondary specialized school (C), college or higher (D). Marriage: married (Yes), unmarried/divorced/widowed (No). $p < 0.05$ and bold text represent statistically significant

ORIGINAL PAPER

Table 4. *Multivariate logistic regression analysis for the relationship between four chronic diseases and obesity indicators*

Item		Hypertension		Diabetes		Dyslipidaemia		Hyperuricaemia	
		OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
		Adjust by age, gender, education level, marriage, smoking status, and WC							
Obese degree									
Normal		1		1		1		1	
Underweight		0.62 (0.18–2.05)	0.428	0.69 (0.09–5.37)	0.727	0.87 (0.53–1.44)	0.593	1.46 (0.48–4.45)	0.501
Overweight		1.55 (1.20–2.00)	0.001	0.87 (0.58–1.31)	0.502	1.59 (1.35–1.89)	< 0.001	1.81 (1.2–2.74)	0.005
Obesity		1.51 (1.06–2.14)	0.021	0.47 (0.26–0.84)	0.011	1.74 (1.35–2.25)	< 0.001	2.15 (1.29–3.6)	0.003
		Adjust by age, gender, education level, marriage, smoking status, and BMI							
Central obesity	No	1		1		1		1	
Yes		1.21 (0.89–1.65)	0.217	1.39 (0.84–2.28)	0.200	1.36 (1.1–1.68)	< 0.001	2.16 (1.38–3.39)	0.001
		Adjust by age, gender, education level, marriage, smoking status, WC, and BMI							
WHtR									
< P25		1		1		1		1	
P25 ≤ WhtR < P50		1.26 (0.87–1.84)	0.224	0.92 (0.49–1.75)	0.800	1.24 (0.99–1.54)	0.060	1.16 (0.68–1.99)	0.577
P50 ≤ WhtR < P75		1.24 (0.82–1.89)	0.311	1.27 (0.64–2.49)	0.495	1.48 (1.11–1.97)	0.007	1.93 (1.06–3.51)	0.032
≥ P75		1.27 (0.75–2.14)	0.376	0.94 (0.4–2.21)	0.887	1.28 (0.87–1.90)	0.210	2.10 (0.98–4.50)	0.056

BMI — body mass index; WC — waist circumference; WHtR — waist-to-height ratio; OR — odds ratio; CI — confidence interval; [a] Group analysis was performed according to quartiles of WHtR. Obese degree: underweight (BMI < 18.5), normal (18.5 ≤ BMI < 24), overweight (24 ≤ BMI < 28), obesity (BMI ≥ 28). Central obesity: male waist circumference ≥ 90 cm or female waist circumference ≥ 80 cm. BMI and WC: BMI 18.5~24 and non-central obesity (No), 24 ≤ BMI < 28 and male waist circumference ≥ 90 cm or female waist circumference ≥ 80 cm (overweight and central obesity), BMI ≥ 28 and male waist circumference ≥ 90 cm or female waist circumference ≥ 80 cm (obesity and central obesity). p < 0.05 and text bold represent statistically significant

Discussion

Numerous studies have confirmed that people with obesity and central obesity are at higher risk for chronic diseases [25, 26]. This study analysed the influence of demographic characteristics, education level, and marital and smoking status on obesity and chronic diseases in the Han population in northern Shaanxi, China through univariate analysis. The relationship between obesity and chronic diseases in this region was also explored.

In this study, we found that the Han population in northwest China has a serious problem of obesity, and the main type of obesity is central. Several studies have confirmed that obesity is a heterogeneous disease, which is affected by multiple factors such as age, region, and environment [27, 28]. Heterogeneity of obesity was also confirmed in this study. Studies have found that marriage increases the risk of overweight and obesity in the Chinese population [29], and smoking is a risk factor for obesity [30]. Our study also found that various types of obesity detection rate for married participants were higher than unmarried/divorced/widowed participants, and smokers showed higher than those in non-smokers. In this study, the rate of central obesity increased with the increase of age, and the rate of overweight and obesity increased most rapidly in the age group of 40–49 years. The results of this study are consistent with previous findings that obesity is more prevalent in older groups [31]. Therefore, it is speculated that the older population investigated area may be the focus population for the prevention and control of overweight, obesity, and central obesity. Similarly, our study and other studies conducted in different populations all found a negative correlation between education level and obesity [32–34]. However, previous studies have reported that obesity is generally more prevalent in women, which is inconsistent with the results found in our study, i.e. that overweight, obesity, and central obesity were all more common in men.

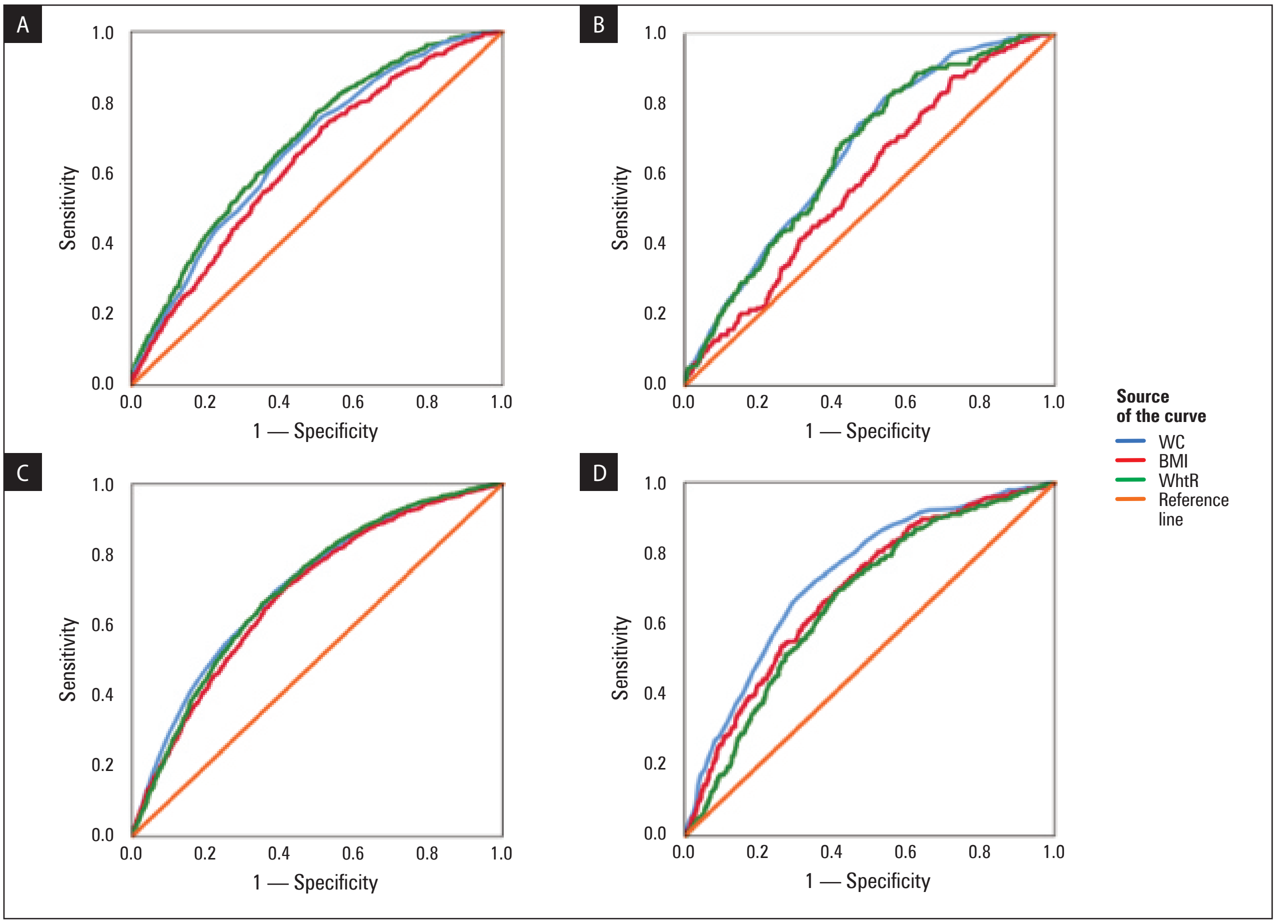

Figure 3. *Receiver operator characteristic (ROC) curve for predicting chronic diseases.* **A.** *ROC for predicting hypertension;* **B.** *ROC for predicting diabetes; C. ROC for predicting lipid abnormality; D. ROC for predicting hyperuricemia. WC — waist circumference; BMI— body mass index; WhtR — waist-to-height ratio.*

We suspect that the reason for the inconsistency may be affected by factors such as the different genetic background of the respondents and the sample size. Based on the above, it can be concluded that obesity is a serious problem in the Han population in northwest China, and it is especially necessary to pay attention to the prevention of obesity among those who are married, older, and with lower education levels.

Previous studies have reported that obesity plays a related pathophysiological role in human health problems, which is the result of complex interaction of genetic, nutritional, and metabolic factors [35]. Studies have found that obesity is closely related to many chronic diseases and their risk factors [36, 37]. Because obesity is a serious problem in the area investigated, this study explored the impact of obesity on chronic diseases in the population of northwest China through multi-factor regression analysis. Rohm et al. reviewed the current understanding of inflammation mechanisms in obesity, type 2 diabetes (T2DM), and related diseases, and found that obesity leads to chronic systemic inflammation and contributes to T2DM [38]. We found that obesity is a protective factor for diabetes in the Han population in northwest China, which seems to be different from previous studies [39, 40]. However, in a meta-analysis of 16 cohort studies that included different ethnic groups in Asia, diabetes was more strongly associated with a measure of central obesity, while hypertension was more strongly associated with BMI [41]. The above studies seem to suggest that obesity types defined by different obesity indicators have different effects on diabetes risk. Based on this, we speculate that the reason why the results of this study are different from those of the predecessors may be that the obesity category of this study is divided according to different obesity indicators. In addition, the fact that the genetic background of the population investigated in this study is different from that of previous studies may also be one of the reasons. Therefore, there is insufficient evidence to directly conclude that obesity ($24 \leq BMI < 28$) is a protective factor for the prevalence of diabetes based on the results of this study. It is necessary to further expand the sample size or research scope for verification and analysis. In addition, the results of this study

Table 5. *Predictive efficacy analysis of obesity indicators for four chronic diseases*

Chronic diseases	Indicators	Item	AUC	Cut-off value	Sensitivity (%)	Specificity (%)	Youden index
Hypertension	BMI	Male	0.61 (0.57–0.64)	23.87	80.50	37.10	0.18
		Female	0.65 (0.62–0.68)	24.27	71.10	53.10	0.24
		Total	0.67 (0.64–0.69)	24.27	72.80	48.60	0.21
	WC	Male	0.64 (0.60–0.67)	93.50	55.30	66.00	0.21
		Female	0.70 (0.67–0.72)	84.50	68.10	60.20	0.28
		Total	0.63 (0.61–0.66)	85.50	72.50	52.00	0.25
	WHtR	Male	0.64 (0.61–0.68)	0.51	84.70	37.10	0.22
		Female	0.71 (0.69–0.74)	0.54	65.40	65.90	0.31
		Total	0.69 (0.66–0.71)	0.52	76.90	50.30	0.27
Diabetes	BMI	Male	0.57 (0.51–0.62)	22.74	89.50	24.20	0.14
		Female	0.58 (0.53–0.64)	23.52	76.70	39.70	0.16
		Total	0.58 (0.55–0.62)	22.74	87.20	28.10	0.15
	WC	Male	0.61 (0.56–0.66)	86.50	84.80	34.60	0.19
		Female	0.69 (0.65–0.74)	79.50	94.40	36.40	0.31
		Total	0.67 (0.63–0.70)	84.50	81.50	46.10	0.28
	WHtR	Male	0.61 (0.55–0.66)	0.52	82.90	39.00	0.22
		Female	0.71 (0.66–0.75)	0.54	73.30	61.40	0.35
		Total	0.66 (0.63–0.70)	0.52	82.10	45.10	0.27
Dyslipidaemia	BMI	Male	0.72 (0.69–0.74)	23.95	77.90	56.90	0.35
		Female	0.66 (0.64–0.68)	24.04	65.90	58.80	0.25
		Total	0.69 (0.67–0.70)	24.04	70.80	58.50	0.29
	WC	Male	0.71 (0.69–0.74)	90.50	60.40	72.60	0.33
		Female	0.69 (0.67–0.71)	82.50	65.30	62.00	0.27
		Total	0.71 (0.69–0.72)	84.50	69.50	61.30	0.31
	WHtR	Male	0.70 (0.68–0.73)	0.52	70.40	63.00	0.33
		Female	0.69 (0.67–0.71)	0.51	73.10	55.70	0.29
		Total	0.70 (0.69–0.72)	0.52	66.00	64.90	0.31
Hyperuricaemia	BMI	Male	0.68 (0.65–0.72)	24.73	78.80	48.70	0.28
		Female	0.62 (0.55–0.69)	24.04	79.20	47.30	0.27
		Total	0.69 (0.66–0.72)	25.54	66.20	62.30	0.29
	WC	Male	0.68 (0.64–0.71)	90.50	72.90	57.00	0.30
		Female	0.60 (0.53–0.68)	84.50	68.80	56.80	0.26
		Total	0.73 (0.71–0.76)	90.50	65.90	70.90	0.37
	WHtR	Male	0.66 (0.63–0.70)	0.54	70.00	55.90	0.26
		Female	0.61 (0.53–0.69)	0.53	64.60	59.10	0.24
		Total	0.67 (0.64–0.69)	0.54	69.40	58.60	0.28

AUC — area under curve; BMI — body mass index; WC — waist circumference; WhtR — waist-to-height ratio

showed that overweight and obesity were risk factors for hypertension, dyslipidaemia, and hyperuricaemia. Central obesity is a risk factor for dyslipidaemia and hyperuricaemia; higher WHtR is a risk factor for dyslipidaemia and hyperuricaemia. Several studies have also reported that obesity has a significant impact on the risk of hypertension, dyslipidaemia, and hyperuricaemia [42–44]. These findings are consistent with this study. Based on the above, it can be inferred that overweight, obesity, and central obesity are risk factors for hyperuricaemia and dyslipidaemia in northwest China. In addition, a number of studies have confirmed that direct use of the World Health Organization recommended BMI threshold (25 kg/m^2) to predict chronic diseases in different regions is not the most appropriate choice. This study showed that the optimal BMI threshold for predicting hypertension in the Han population in Northern Shaanxi, China was 24.27 (male: 23.87; female: 24.27), dyslipidaemia was 24.04 (male: 23.95; female: 24.04), and hyperuricaemia was: 25.54 (male: 24.73; female: 24.04). The results of this study are similar to those of previous studies in other regions [45–48]. We also found a strong correlation between WC or WHtR and increased risk of dyslipidaemia and hyperuricaemia. The results showed that the optimal WC and WHtR thresholds for predicting dyslipidaemia were 84.5 (male: 90.5; female: 82.5) and 0.52 (male: 0.52; female: 0.51), respectively, and the optimal WC and WHtR thresholds for predicting hyperuricaemia were 90.5 (male: 90.5; female: 84.5) and 0.54 (male: 0.54; female: 0.53), respectively. Compared with previous studies, it was found that the optimal cut-off values of WC and WHtR for predicting chronic diseases in the investigated subjects were higher than in other populations [13, 19]. The reasons for the differences in the above results may be related to genetic background, diet, living habits, and other differences in different regions. On the other hand, it may also be related to the differences between the diagnostic criteria of related diseases in this study and those used in other studies. Combined with the results of previous studies and this study, it is further proven that it is particularly important to determine the appropriate critical value of obesity indicators for predicting chronic diseases in different regional backgrounds.

Our study is the first to conduct an epidemiological study of obesity in Northern Shaanxi, China. The relationship between obesity-related indicators and chronic diseases and their predictive value in this region were analysed for the first time. It is worth noting that this study has certain limitations, and the sensitivity of the cut-point determination of obesity-related indicators is low. Therefore, it is necessary to expand the scope of the survey object area for further investigation and research under different circumstances, which will help to further confirm the results of this study.

Conclusion

Overweight, obesity, and central obesity are serious problems in northern Shaanxi, China, and central obesity is the main problem. Obesity-related indicators BMI, WC, and WHtR are strongly correlated with increased risk of chronic diseases in Northern Shaanxi, China. This study has provided a scientific basis for formulating long-term development plans for obesity prevention and control in northern Shaanxi, and it has provided a valuable reference for obesity indicators for predicting chronic risk in clinics.

Ethical approval and consent to participate

This study protocol was reviewed and approved by Shenmu Hospital, approval number No. sm004. All participants signed informed consent forms before participating in this study.

Consent for publication

All authors agreed to publish the manuscript.

Availability of data and materials

The datasets used and analysed in the current study are available from the corresponding author on reasonable request.

Conflict of interests

The authors declare that they have no conflict of interest.

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Authors' contributions

Y.L. conceived and designed the experiments; X.Y. and X.H. performed the experiments; M.L. collected samples; Y.H. and X.W. analysed the data; X.Y. and X.H. drafted the paper; Y.L. reviewed the paper.

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References

1. Khanna D, Rehman A. Pathophysiology of Obesity. StatPearls, Treasure Island 2022.
2. Nyberg ST, Batty GD, Pentti J, et al. Obesity and loss of disease-free years owing to major non-communicable diseases: a multicohort study. Lancet Public Health. 2018; 3(10): e490–e497, doi: 10.1016/S2468-2667(18)30139-7, indexed in Pubmed: 30177479.
3. Afshin A, Forouzanfar MH, Reitsma MB, et al. GBD 2015 Obesity Collaborators. Health Effects of Overweight and Obesity in 195 Countries over 25 Years. N Engl J Med. 2017; 377(1): 13–27, doi: 10.1056/NEJMoa1614362, indexed in Pubmed: 28604169.
4. Petrovskis A, Baquero B, Bekemeier B. Involvement of Local Health Departments in Obesity Prevention: A Scoping Review. J Public Health Manag Pract. 2022; 28(2): E345–E353, doi: 10.1097/PHH.0000000000001346, indexed in Pubmed: 33729187.
5. Dhawan D, Sharma S. Abdominal Obesity, Adipokines and Non-communicable Diseases. J Steroid Biochem Mol Biol. 2020; 203: 105737, doi: 10.1016/j.jsbmb.2020.105737, indexed in Pubmed: 32818561.
6. Dampoudani N, Giakouvaki A, Diamantoudi D, et al. Physical Activity, Body Mass Index (BMI) and Abdominal Obesity of Pre-Adolescent Children in the Region of Thrace, NE Greece, in Relation to Socio-Demographic Characteristics. Children (Basel). 2022; 9(3), doi: 10.3390/children9030340, indexed in Pubmed: 35327711.
7. Zhang X, Chen H, Gu K, et al. Association of Body Mass Index and Abdominal Obesity with the Risk of Airflow Obstruction: National Health and Nutrition Examination Survey (NHANES) 2007-2012. COPD. 2022; 19(1): 99–108, doi: 10.1080/15412555.2022.2032627, indexed in Pubmed: 35385365.
8. Frank AP, de Souza Santos R, Palmer BF, et al. Determinants of body fat distribution in humans may provide insight about obesity-related health risks. J Lipid Res. 2019; 60(10): 1710–1719, doi: 10.1194/jlr.R086975, indexed in Pubmed: 30097511.
9. Cong X, Liu S, Wang W, et al. Combined consideration of body mass index and waist circumference identifies obesity patterns associated with risk of stroke in a Chinese prospective cohort study. BMC Public

Health. 2022; 22(1): 347, doi: 10.1186/s12889-022-12756-2, indexed in Pubmed: 35180873.
10. Hariharan R, Odjidja EN, Scott D, et al. The dietary inflammatory index, obesity, type 2 diabetes, and cardiovascular risk factors and diseases. Obes Rev. 2022; 23(1): e13349, doi: 10.1111/obr.13349, indexed in Pubmed: 34708499.
11. Stasi A, Cosola C, Caggiano G, et al. Obesity-Related Chronic Kidney Disease: Principal Mechanisms and New Approaches in Nutritional Management. Front Nutr. 2022; 9: 925619, doi: 10.3389/fnut.2022.925619, indexed in Pubmed: 35811945.
12. Du H, Ren X, Bai J, et al. Research Progress of Ferroptosis in Adiposity-Based Chronic Disease (ABCD). Oxid Med Cell Longev. 2022; 2022: 1052699, doi: 10.1155/2022/1052699, indexed in Pubmed: 35502211.
13. Swainson MG, Batterham AM, Tsakirides C, et al. Prediction of whole-body fat percentage and visceral adipose tissue mass from five anthropometric variables. PLoS One. 2017; 12(5): e0177175, doi: 10.1371/journal.pone.0177175, indexed in Pubmed: 28493988.
14. Li S, Wang Y, Ying Y, et al. Independent and Joint Associations of BMI and Waist Circumference With the Onset of Type 2 Diabetes Mellitus in Chinese Adults: Prospective Data Linkage Study. JMIR Public Health Surveill. 2023; 9: e39459, doi: 10.2196/39459, indexed in Pubmed: 36630180.
15. Shri N, Singh S, Singh A. Prevalence and Predictors of Combined Body Mass Index and Waist Circumference Among Indian Adults. Int J Public Health. 2023; 68: 1605595, doi: 10.3389/ijph.2023.1605595, indexed in Pubmed: 37065643.
16. Sayeed MA, Mahtab H, Latif ZA, et al. Waist-to-height ratio is a better obesity index than body mass index and waist-to-hip ratio for predicting diabetes, hypertension and lipidemia. Bangladesh Med Res Counc Bull. 2003; 29(1): 1–10, indexed in Pubmed: 14674615.
17. Conway JM, Yanovski SZ, Avila NA, et al. Visceral adipose tissue differences in black and white women. Am J Clin Nutr. 1995; 61(4): 765–771, doi: 10.1093/ajcn/61.4.765, indexed in Pubmed: 7702017.
18. Wang J, Yang Ym, Zhu J, et al. Overweight is associated with improved survival and outcomes in patients with atrial fibrillation. Clin Res Cardiol. 2014; 103(7): 533–542, doi: 10.1007/s00392-014-0681-7, indexed in Pubmed: 24535378.
19. Lim J, Park HS. Trends in the prevalence of underweight, obesity, abdominal obesity and their related lifestyle factors in Korean young adults, 1998-2012. Obes Res Clin Pract. 2018; 12(4): 358–364, doi: 10.1016/j.orcp.2017.04.004, indexed in Pubmed: 28483477.
20. Alshamiri MQ, Mohd A Habbab F, Al-Qahtani SS, et al. Waist-to-Height Ratio (WHtR) in Predicting Coronary Artery Disease Compared to Body Mass Index and Waist Circumference in a Single Center from Saudi Arabia. Cardiol Res Pract. 2020; 2020: 4250793, doi: 10.1155/2020/4250793, indexed in Pubmed: 32257425.
21. Yin R, Yin L, Li L, et al. Hypertension in China: burdens, guidelines and policy responses: a state-of-the-art review. J Hum Hypertens. 2022; 36(2): 126–134, doi: 10.1038/s41371-021-00570-z, indexed in Pubmed: 34215840.
22. Jia W, Weng J, Zhu D, et al. Chinese Diabetes Society. Standards of medical care for type 2 diabetes in China 2019. Diabetes Metab Res Rev. 2019; 35(6): e3158, doi: 10.1002/dmrr.3158, indexed in Pubmed: 30908791.
23. Song Q, Liu X, Zhou W, et al. Night sleep duration and risk of each lipid profile abnormality in a Chinese population: a prospective cohort study. Lipids Health Dis. 2020; 19(1): 185, doi: 10.1186/s12944-020-01363-y, indexed in Pubmed: 32799877.
24. Li Q, Li X, Wang J, et al. Diagnosis and treatment for hyperuricemia and gout: a systematic review of clinical practice guidelines and consensus statements. BMJ Open. 2019; 9(8): e026677, doi: 10.1136/bmjopen-2018-026677, indexed in Pubmed: 31446403.
25. Janssen I, Katzmarzyk PT, Ross R. Waist circumference and not body mass index explains obesity-related health risk. Am J Clin Nutr. 2004; 79(3): 379–384, doi: 10.1093/ajcn/79.3.379, indexed in Pubmed: 14985210.
26. Pan WH, Flegal KM, Chang HY, et al. Body mass index and obesity-related metabolic disorders in Taiwanese and US whites and blacks: implications for definitions of overweight and obesity for Asians. Am J Clin Nutr. 2004; 79(1): 31–39, doi: 10.1093/ajcn/79.1.31, indexed in Pubmed: 14684394.
27. Cooper AJ, Gupta SR, Moustafa AF, et al. Sex/Gender Differences in Obesity Prevalence, Comorbidities, and Treatment. Curr Obes Rep. 2021; 10(4): 458–466, doi: 10.1007/s13679-021-00453-x, indexed in Pubmed: 34599745.
28. Chooi YuC, Ding C, Magkos F. The epidemiology of obesity. Metabolism. 2019; 92: 6–10, doi: 10.1016/j.metabol.2018.09.005, indexed in Pubmed: 30253139.
29. Liu J, Garstka MA, Chai Z, et al. Marriage contributes to higher obesity risk in China: findings from the China Health and Nutrition Survey. Ann Transl Med. 2021; 9(7): 564, doi: 10.21037/atm-20-4550, indexed in Pubmed: 33987262.
30. Sucharda P. [Smoking and obesity]. Vnitr Lek. 2010; 56(10): 1053–1057, indexed in Pubmed: 21105451.
31. Sørensen TIA, Martinez AR, Jørgensen TS. Epidemiology of Obesity. Handb Exp Pharmacol. 2022; 274: 3–27, doi: 10.1007/164_2022_581, indexed in Pubmed: 35419622.
32. Hsieh TH, Lee JJ, Yu EWR, et al. Association between obesity and education level among the elderly in Taipei, Taiwan between 2013 and 2015: a cross-sectional study. Sci Rep. 2020; 10(1): 20285, doi: 10.1038/s41598-020-77306-5, indexed in Pubmed: 33219305.
33. Kim TJ, Roesler NM, von dem Knesebeck O. Causation or selection — examining the relation between education and overweight/obesity in prospective observational studies: a meta-analysis. Obes Rev. 2017; 18(6): 660–672, doi: 10.1111/obr.12537, indexed in Pubmed: 28401630.
34. Li Yi, Cai T, Wang H, et al. Achieved educational attainment, inherited genetic endowment for education, and obesity. Biodemography Soc Biol. 2021; 66(2): 132–144, doi: 10.1080/19485565.2020.1869919, indexed in Pubmed: 34182851.
35. De Lorenzo A, Soldati L, Sarlo F, et al. New obesity classification criteria as a tool for bariatric surgery indication. World J Gastroenterol. 2016; 22(2): 681–703, doi: 10.3748/wjg.v22.i2.681, indexed in Pubmed: 26811617.
36. Lara M, Bustos P, Amigo H, et al. Is waist circumference a better predictor of blood pressure, insulin resistance and blood lipids than body mass index in young Chilean adults? BMC Public Health. 2012; 12: 638, doi: 10.1186/1471-2458-12-638, indexed in Pubmed: 22882972.
37. Li Xu, Katashima M, Yasumasu T, et al. Visceral fat area, waist circumference and metabolic risk factors in abdominally obese Chinese adults. Biomed Environ Sci. 2012; 25(2): 141–148, doi: 10.3967/0895-3988.2012.02.003, indexed in Pubmed: 22998819.
38. Rohm TV, Meier DT, Olefsky JM, et al. Inflammation in obesity, diabetes, and related disorders. Immunity. 2022; 55(1): 31–55, doi: 10.1016/j.immuni.2021.12.013, indexed in Pubmed: 35021057.
39. Zang BY, He LX, Xue L. Intermittent Fasting: Potential Bridge of Obesity and Diabetes to Health? Nutrients. 2022; 14(5), doi: 10.3390/nu14050981, indexed in Pubmed: 35267959.
40. Bragg F, Tang K, Guo Yu, et al. China Kadoorie Biobank (CKB) Collaborative Group. Associations of General and Central Adiposity With Incident Diabetes in Chinese Men and Women. Diabetes Care. 2018; 41(3): 494–502, doi: 10.2337/dc17-1852, indexed in Pubmed: 29298802.
41. Nyamdorj R, Qiao Q, Lam TH, et al. Decoda Study Group. BMI compared with central obesity indicators in relation to diabetes and hypertension in Asians. Obesity (Silver Spring). 2008; 16(7): 1622–1635, doi: 10.1038/oby.2008.73, indexed in Pubmed: 18421260.
42. Movahed MR, Lee JZ, Lim WY, et al. Strong independent association between obesity and essential hypertension. Clin Obes. 2016; 6(3): 189–192, doi: 10.1111/cob.12139, indexed in Pubmed: 27166134.
43. Duttaroy AK. Role of Gut Microbiota and Their Metabolites on Atherosclerosis, Hypertension and Human Blood Platelet Function: A Review. Nutrients. 2021; 13(1), doi: 10.3390/nu13010144, indexed in Pubmed: 33401598.
44. Sun J, Sun M, Su Y, et al. Mediation effect of obesity on the association between triglyceride-glucose index and hyperuricemia in Chinese hypertension adults. J Clin Hypertens (Greenwich). 2022; 24(1): 47–57, doi: 10.1111/jch.14405, indexed in Pubmed: 34904367.
45. Nishida C, Ko GT, Kumanyika S. Body fat distribution and noncommunicable diseases in populations: overview of the 2008 WHO Expert Consultation on Waist Circumference and Waist-Hip Ratio. Eur J Clin Nutr. 2010; 64(1): 2–5, doi: 10.1038/ejcn.2009.139, indexed in Pubmed: 19935820.
46. Liu Y, Tong G, Tong W, et al. Can body mass index, waist circumference, waist-hip ratio and waist-height ratio predict the presence of multiple metabolic risk factors in Chinese subjects? BMC Public Health. 2011; 11: 35, doi: 10.1186/1471-2458-11-35, indexed in Pubmed: 21226967.
47. Sinaga M, Worku M, Yemane T, et al. Optimal cut-off for obesity and markers of metabolic syndrome for Ethiopian adults. Nutr J. 2018; 17(1): 109, doi: 10.1186/s12937-018-0416-0, indexed in Pubmed: 30466421.
48. Li Q, Li R, Zhang S, et al. Relation of BMI and waist circumference with the risk of new-onset hyperuricemia in hypertensive patients. QJM. 2022; 115(5): 271–278, doi: 10.1093/qjmed/hcaa346, indexed in Pubmed: 33486528.