

Table S1 Diagnostic criterion for clinical obesity in adults according to the 2025 clinical obesity guideline[1]and the 9 specific criteria utilized in this Study

	Organ, tissue, or body system	Diagnostic criterion	9 specific criteria utilized in this study
1	CNS	Signs of raised intracranial pressure such as vision loss and/or recurrent headaches	—
2	Upper airways	Apnoeas/hypopnoeas during sleep due to increased upper airways resistance	—
3	Respiratory	Hypoventilation and/or breathlessness and/or wheezing due to reduced lung and/or diaphragmatic compliance	—
4	Cardiovascular (ventricular)	Reduced Left Ventricular systolic function - Heart Failure with Reduced Ejection Fraction	Patient-reported history of heart failure.
5	Cardiovascular (atrial)	Chronic/recurrent atrial fibrillation	SBP/DBP $\geq$ 130/ 85 mmHg or the use of antihypertensive medication, or a self-reported history of hypertension.
6	Cardiovascular (pulmonary)	Pulmonary artery hypertension	—
7	Cardiovascular	Pulmonary artery hypertension	—
8	Cardiovascular (thrombosis)	Recurrent DVT and/or pulmonary thromboembolic disease	—

Table S1 (continued)

	Organ, tissue, or body system	Diagnostic criterion	9 specific criteria utilized in this Study
9	Cardiovascular (arterial)	Raised arterial blood pressure	—
10	Metabolism	The cluster of hyperglycaemia, high TG levels, and low HDL-C levels	Diabetes was defined as fasting plasma glucose ≥ 7.0 mmol/L, or HbA1c $\geq 6.5\%$, or previously diagnosis of diabetes, or using antidiabetic drugs; Prediabetes was defined as fasting plasma glucose levels ranging from 5.6 to 6.9 mmol/L or HbA1c levels between 5.7% and 6.4%; Hypertriglyceridemia was defined as TG ≥ 1.70 mmol/L; Decreased HDL-C was defined as HDL-C <1.0 mmol/L in men or <1.30 mmol/L in women.
11	Liver	NAFLD with hepatic fibrosis	NAFLD, characterized by a FLI ≥ 60 , with no history of alcohol consumption. Hepatic fibrosis, characterized by a FIB-4 > 2.67
12	Renal	Microalbuminuria with reduced eGFR	Urine Albumin-to-Creatinine Ratio ≥ 30 mg/g or estimated glomerular filtration rate < 60 mL/min/1.73 m ²
13	Urinary	Recurrent/chronic urinary incontinence	The grading of incontinence defined by using two parameters, including incontinence frequency (less than monthly, several times per month, several times per week or per day) and urine leakage (count drops, splash, or more). The total score was obtained by multiplying the scores of the two parameters, ranging from 1 to 12 (1-2 mild incontinence; 3-6 moderate incontinence; 7-12severe incontinence). Patients with a total score ≥ 1 were considered to exhibit symptoms or signs of obesity-related urinary system disorders.

Table S1 (continued)

	Organ, tissue, or body system	Diagnostic criterion	9 specific criteria utilized in this Study
14	Reproductive (female)	Anovulation, oligo-menorrhea and Polycystic Ovary Disease	menstrual thinning, infertility, and hyperandrogenemia. Hyperandrogenemia was defined as testosterone > 30 ng/dL or free androgen index > 5.0.
15	Reproductive (male)	Male hypogonadism	hypotestosteronemia (testosterone < 300 ng/dL).
16	Musculoskeletal	Chronic, severe knee or hip pain associated with joint stiffness and reduced range of joint motion	——
17	Lymphatic	Lower limbs lymphedema causing chronic pain and/or reduced range of motion	——
18	Limitations of day-to-day activities	Significant, age-adjusted limitations of mobility and/or other basic Activities of Daily Living	Functional limitations in daily activities were assessed using the modified Barthel Index, which evaluates domains including eating, bathing, dressing, personal hygiene, urine control, toilet use, transfer from chair to bed, walking, and the ability to walk up and down stairs. According to the score assessed with the Barthel index, patients can be divided into 5 groups: complete dependence (0-20), severe dependence (21-60), moderate dependence (61-90), mild dependence (91-99), and independent (100). Patient with score <100 was considered daily activity limitation.

Abbreviations: HbA1c, glycosylated hemoglobin; eGFR, estimated glomerular filtration rate; DVT, deep vein thrombosis; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol.

Table S2 Staging of ORCs according to the 2016 AACE/ACE obesity guideline[2] and the 9 specific criteria utilized in this Study

ORCs	Grading standards	Specific criteria utilized in this Study
Prediabetes, Metabolic Syndrome, and T2D		
Stage 0 (none)	No risk factors related to insulin resistance (WC, BP, HDL-C, TG, fasting glucose). This is equivalent to (CMDS)[3] stage 0.	No risk factors related to insulin resistance (①-⑤): ①WC ≥ 102 cm(male)/ ≥ 88 cm (female); ②SBP/DBP $\geq 130/85$ mm/Hg; ③HDL-C ≥ 1.0 mmol/L(male)/ ≥ 1.3 mmol/(female); ④TG ≥ 1.7 mmol/L; ⑤IFG
Stage 1 (mild-moderate)	1 or 2 risk factors (WC, BP, HDL-C, TG) This is equivalent to CMDS stage 1.	1-2 risk factors related to insulin resistance (①-⑤)
Stage 2 (severe)	Prediabetes, Metabolic Syndrome, or T2D. This is equivalent to CMDS stage 2-4.	Meeting any one of the following conditions: (1) prediabetes; (2) T2D; (3) metabolic syndrome
Hypertension		
Stage 0 (none)	SBP/DBP $< 130/85$ mm/Hg	SBP/DBP $<130/85$ mm/Hg

Table S2 (continued)

ORCs	Grading standards	Specific criteria utilized in this Study
Stage 1 (mild-moderate)	SBP/DBP $\geq$ 130/85 mm/Hg in absence of other risk factors	Meeting any two of the following conditions: (1) SBP/DBP $\geq$ 130/85 mm/Hg; (2) No risk factors related to insulin resistance(①-⑤)
Stage 2 (severe)	SBP/DBP target not met despite use of anti-hypertensive medication(s); BP $\geq$ 130/85 mm/Hg in high-risk individual: CMDS stage 2-4, smoking, African American, congestive heart failure	Meeting any two of the following conditions: (1) BP target not met (SBP/DBP $\geq$ 130/85 mm/Hg) despite use of anti-hypertensive medication; (2) BP $\geq$ 130/85 mm/Hg in high risk individual: CMDS 2-4, smoking, African American, congestive heart failure.
Hypertriglyceridemia/Dyslipidemia		
Stage 0 (none)	TG < 150 and HDL-C $\geq$ 40 in male and $\geq$ 50 in female	Meeting any two of the following conditions: (1) TG<1.7 mmol/L; (2) HDL-C $\geq$ 1.0 mmol/L(male)/ $\geq$ 1.3 mmol/L(female)
Stage 1 (mild-moderate)	TG 150-399 mg/dL and/or HDL-C < 40 in male and < 50 in female in absence of other risk factors	Meeting any one of the conditions listed in (1) or (2), while also fulfilling the requirement in (3): (1) TG 1.7-4.5 mmol/L; (2) HDL-C<1.0 mmol/L(male)/ <1.3 mmol/L(female); (3) No risk factors related to insulin resistance(①-⑤)

Table S2 (continued)

ORCs	Grading standards	Specific criteria utilized in this Study
Stage 2 (severe)	TG ≥ 400 in absence of other risk factors; TG ≥ 150 and HDL-C < 40 in male and < 50 in female in high risk individual: CMDS stage 2-4	Meeting any one of the following conditions: (1) TG ≥ 4.5 mmol/L; (2) TG ≥ 150 and HDL-C < 40 in male and < 50 in female in high-risk individual: CMDS stage 2-4
Sleep apnea		
Stage 0 (none)	No symptoms, AHI < 5	——
Stage 1 (mild-moderate)	AHI 5-29 with no or mild symptoms	——
Stage 2 (severe)	AHI ≥ 30 ; AHI 5-29 with severe symptoms and/or clinical consequences	——
Non-alcoholic fatty liver disease		
Stage 0 (none)	No steatosis	FLI < 60
Stage 1 (mild-moderate)	Presence of steatosis but no inflammation or fibrosis	FLI > 60 and FIB-4 < 2.67
Stage 2 (severe)	Steatohepatitis (NASH)	FIB-4 > 2.67
Polycystic ovary disease		
Stage 0 (none)	Does not meet criteria, absence of polycystic ovary disease	——
Stage 1 (mild-moderate)	1 or 2 risk factors (WC, BP, HDL-C, TG: CMDS stage 1) and no infertility/anovulation	——

Table S2 (continued)

ORCs	Grading standards	Specific criteria utilized in this Study
Stage 2 (severe)	Infertility/anovulation Oligomenorrhea; Menorrhagia Prediabetes/Metabolic Syndrome/T2D (CMDS stage 2-4)	——
Osteoarthritis		
Stage 0 (none)	No symptoms and no radiographic joint changes	No history of osteoarthritis, and a modified Barthel Index score of 100.
Stage 1 (mild-moderate)	Mild-moderate symptoms and functional impairment (e.g., validated questionnaire) and/or mild-moderate anatomical joint changes	A history of osteoarthritis, and a modified Barthel Index score between 61 and 99.
Stage 2 (severe)	Moderate-severe symptoms and functional impairment (e.g., validated questionnaire) and/or moderate-severe anatomical joint changes S/P knee or hip replacement surgery	A history of osteoarthritis, and a modified Barthel Index score between 0 and 60.
Stress and urge urinary incontinence		
Stage 0 (none)	No symptoms and/or normal urodynamics	A urinary incontinence score of 0.
Stage 1 (mild-moderate)	Mild-moderate symptom severity score	A urinary incontinence score between 1 and 6.

Table S2 (continued)

ORCs	Grading standards	Specific criteria utilized in this Study
Stage 2 (severe)	Severe symptom severity score	A urinary incontinence score between 7 and 12.
Gastroesophageal reflux disease		
Stage 0 (none)	No symptoms or findings	——
Stage 1 (mild-moderate)	Mild-moderate symptoms	——
Stage 2 (severe)	Severe symptoms Erosive esophagitis Barrett's Esophagus (if not accompanied by progressive weight loss)	——
Disability/Immobility		
Stage 0 (none)	No specific diagnostic	A modified Barthel Index score of 100.
Stage 1 (mild-moderate)	criteria were provided.	A modified Barthel Index score between 0 and 60.
Stage 2 (severe)		A modified Barthel Index score between 61 and 99.
Psychological disorder/Stigmatization		
Stage 0 (none)	No specific diagnostic	A PHQ-9 score between 0 and 4.
Stage 1 (mild-moderate)	criteria were provided.	A PHQ-9 score between 5 and 14.
Stage 2 (severe)		A PHQ-9 score of 15 or higher.

Abbreviations: AACE/ACE, American Association of Clinical Endocrinologists and American College of Endocrinology; TG, triglycerides; IFG, impaired fasting glucose; DBP, diastolic blood pressure; SBP, systolic blood pressure; BP, blood pressure; WC, waist circumference; HDL-C, high-density lipoprotein cholesterol; CMDS,

cardiometabolic disease staging; AHI, apnea hypopnea index; FLI, fatty liver Index; FIB-4, fibrosis 4 score; NASH, nonalcoholic steatohepatitis; S/P, status post; ORCs, obesity-related complications; T2D, type 2 diabetes;

Table S3 The Cardiometabolic Disease Staging System (CMDS) [3]

Stage	Descriptor	Criteria
Stage 0	Metabolically Healthy	No risk factors
Stage 1	One or two risk factors	Have one or two of the following risk factors: (1) High WC (≥ 112 cm in men, ≥ 88 cm in women) (2) SBP/DBP $\geq$ or on anti-hypertensive medication (3) Reduced serum HDL-C (< 1.0 mmol/L in men; < 1.3 mmol/L in women) or on medication (4) Elevated fasting serum triglycerides (≥ 1.7 mmol/L) or on medication
Stage 2	Metabolic syndrome or prediabetes	Have only one of the following three conditions in isolation (1) Metabolic Syndrome based on three or more of four risk factors: high waist circumference, elevated blood pressure, reduced HDL-C, and elevated triglycerides (2) IFG (fasting glucose ≥ 5.6 mmol/L) (3) IGT (2-hour glucose ≥ 7.8 mmol/L)
Stage 3	Metabolic syndrome+ prediabetes	Have any two of the following three conditions: (1) Metabolic syndrome (2) IFG (3) IGT
Stage 4	T2D and/or CVD	Have T2D and/or CVD: (1) T2D (fasting glucose ≥ 126 mg/dL or 2-hour glucose ≥ 200 mg/dL or on anti-diabetic therapy) (2) Active CVD (angina pectoris, or status post a CVD event such as acute coronary artery syndrome, stent placement, coronary artery bypass, thrombotic stroke, non-traumatic amputation due to peripheral vascular disease)

Abbreviations: CMDS, cardiometabolic disease staging; T2D, type 2 diabetes; CVD, Cardiovascular Disease; TG, triglycerides; IFG, Impaired Fasting Glucose; IGT, Impaired Glucose Tolerance; HDL-C, high-density lipoprotein cholesterol; BP, blood pressure; WC, waist circumference;

Table S4 General Characteristics of study participants across tertiles of serum RC concentration

Characteristics	Tertiles of serum RC concentration			P for trend
	Tertile 1	Tertile 2	Tertile 3	
Basic Characteristics				
Sex, male (%)	431(45.29)	548(50.27)	683(65.56)	<0.001
Age, years	36(27,46)	45(35,53)	42(33,51)	<0.001
Education level (%)				<0.05
Less than high school	196(13.43)	228(15.16)	252(17.44)	
high school	250(21.17)	247(23.1)	240(23.13)	
more than high school	623(65.41)	597(61.73)	573(59.43)	
unknow	1(0)	0(0)	0(0)	
Race (%)				<0.001
Mexican American	151(10.38)	201(13.53)	209(13.51)	
Other Hispanic	117(8.02)	127(8.42)	137(8.73)	
Non-Hispanic White	309(54.85)	374(59.23)	412(63.14)	
Non-Hispanic Black	327(17.48)	208(10.8)	103(5.25)	
Other	166(9.27)	162(8.02)	204(9.37)	

Table S4 (continued)

Characteristics	Tertiles of serum RC concentration			P for trend
	Tertile 1	Tertile 2	Tertile 3	
Smoking history (%)	335(32.39)	411(41.31)	496(47.88)	<0.001
Alcohol consumption history (%)	663(66.6)	654(66.17)	617(63.05)	0.37
BMI $\geq$ 30 kg/m ² (%)	473(41.51)	543(51.27)	602(58.03)	
WC $\geq$ 102cm(male)/88cm (female) (%)	533(49.74)	633(61.42)	643(63.45)	<0.001
WHtR > 0.5(%)	1054(98.53)	1066(99.44)	1064(99.98)	<0.01
SBP, mmHg	115(107,122)	125(115,135)	122(113,130)	<0.001
DBP, mmHg	70(64,76)	75(69,83)	75(68,81)	<0.001
Laboratory test				
TG, mmol/L	0.98(0.7,1.34)	1.49(0.98,2.16)	1.99(1.68,2.53)	<0.001
TG>4.5 mmol/L (%)	0(0)	0(0)	1(0.08)	0.32
LDL-C, mmol/L	2.922(2.379,3.491)	3.051(2.457,3.646)	3.155(2.56,3.827)	<0.001
HDL-C, mmol/L	1.34(1.16,1.58)	1.14(0.96,1.37)	1.06(0.93,1.24)	<0.001
TC, mmol/L	4.78(4.24,5.46)	4.99(4.32,5.69)	5.28(4.65,6.00)	<0.001
RC, mmol/L	0.44(0.31,0.62)	0.677(0.45,0.98)	0.906(0.77, 1.16)	<0.001
Non-HDL, mmol/L	3.42(2.82,4.04)	3.78(3.11,4.53)	4.18(3.54,4.83)	<0.001
HbA1c, %	5.3(5.1,5.5)	5.6(5.3,6.0)	5.5(5.2,5.8)	<0.001
ALT, U/L	21(16,28)	26(19,36)	27(20,37)	<0.001
AST, U/L	21(18,25)	23(19,29)	23(19,29)	<0.001
GGT, U/L	18(13,26)	25(17,41)	26(19,44)	<0.001

Table S4 (continued)

Characteristics	Tertiles of serum RC concentration			P for trend
	Tertile 1	Tertile 2	Tertile 3	
Serum ALB, g/dL	4.30(4.10,4.50)	4.20(4.00, 4.40)	4.30(4.10,4.50)	0.15
Serum creatinine, umol/L	73.37(61.88,84.86)	73.37 (61.88,84.86)	76.02(63.65,87.52)	<0.001
Uric acid, umol/L	321.20 (267.7, 368.80)	345.00 (285.50,398.50)	350.9 (297.40, 404.50)	<0.001
eGFR, ml/min/1.73m ²	111.33(87.91,136.77)	103.73(80.76,130.32)	111.28(86.74,136.74)	0.3
Drug for dyslipidemia	70(6.71)	102(10.42)	137(13.84)	<0.001
Drug for hypertension	145(11.58)	159(14.45)	209(20.76)	<0.001
Body composition				
BF, %	34.8(28.3,42.4)	36.2(30,43.6)	33.1(28.3,42.2)	0.1
BF ≥ 30%(male)/40% (female) (%)	539(50.8)	608(59.57)	581(56.47)	0.08
Total abdominal fat area, cm ²	421.7(330.87,564.42)	557.8(427.32,700.4)	513.15(384.3,651.71)	<0.001
SFA, cm ²	329.48(250.9,447.23)	411.09(302.88,531.8)	368.35 (266.84,488.31)	0.16
VFA, cm ²	93.64 (67.42, 124.09)	139.53(104.9,183.64)	135.39 (102.08,177.05)	<0.001
VFA ≥ 100cm ² (%)	387(38)	642(60.81)	790(76.15)	<0.001
VSR	0.28(0.2,0.37)	0.36(0.25,0.48)	0.38(0.28,0.49)	<0.001
ASM, kg	23.08(17.87,27.25)	25.2(20.99,29.86)	25.2(20.53,29.18)	<0.001
ASMI, kg/m ²	8.02(6.79,9.06)	8.68(7.67,9.78)	8.58(7.65,9.56)	<0.001

^a Continuous variables are represented by Mean ± SD or Median (IQR), while categorical variables are denoted by numbers (weighted proportions).

Abbreviations: BMI, body mass index; ALT, alanine aminotransferase; AST, aspartate aminotransferase; GGT, gamma-glutamyl transferase; DBP, diastolic blood pressure; SBP, systolic blood pressure; WC, waist circumference; WHtR, waist-to-height ratio; TG, triglycerides; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; TC, total cholesterol; RC, remnant cholesterol; HbA1c, glycosylated hemoglobin; ALB, albumin; eGFR, estimated glomerular filtration rate; AMI, acute myocardial infarction; BF, Body fat percentage; SFA, subcutaneous fat area; VFA, visceral fat area; VSR, visceral-to-subcutaneous fat ratio; ASM, appendicular skeletal muscle mass; ASMI, appendicular skeletal muscle index.

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