



ORIGINAL ARTICLE

Epidemiology/Genetics

Epidemiology and Natural History of Preclinical and Clinical Obesity: Insights From a UK Cohort

Sohail Zahid¹  | Zhiqi Yao¹  | Seraj N. Grimes² | April Kim³ | Allison W. Peng¹ | Roger S. Blumenthal¹ | Marios Arvanitis⁴ | Alexis Battle^{2,3,5,6} | Michael J. Blaha¹

¹Ciccarone Center for the Prevention of Cardiovascular Disease, Johns Hopkins University School of Medicine, Baltimore, Maryland, USA | ²Department of Biomedical Engineering, Johns Hopkins University School of Medicine, Baltimore, Maryland, USA | ³Department of Computer Science, Johns Hopkins University, Baltimore, Maryland, USA | ⁴Department of Cardiology, The Ohio State University, Columbus, Ohio, USA | ⁵Department of Genetic Medicine, Johns Hopkins University School of Medicine, Baltimore, Maryland, USA | ⁶Malone Center for Engineering in Healthcare, Johns Hopkins University, Baltimore, Maryland, USA

Correspondence: Sohail Zahid (szahid1@jh.edu)

Received: 6 October 2025 | **Revised:** 19 November 2025 | **Accepted:** 3 December 2025

Keywords: cardiovascular disease | epidemiology | obesity

ABSTRACT

Objective: Obesity has been traditionally defined by BMI alone, but this metric has limitations in assessing body fat composition and adiposity complications. The Lancet Diabetes and Endocrinology Commission (LDEC) issued a new obesity definition to address these challenges, stratified by preclinical and clinical groups. We evaluated the epidemiology of preclinical and clinical obesity in the UK Biobank and associations with incident cardiovascular disease (CVD).

Methods: We performed retrospective cohort analyses of 502,233 adults enrolled in the UK Biobank. Obesity was categorized using the new definition from LDEC. Clinical obesity was defined as adiposity-related dysfunction assessed via ICD10 codes, physical immobility, and abnormal laboratory values. Preclinical obesity had no additional metabolic deficits.

Results: The prevalence of preclinical and clinical obesity was 31.2% and 36.6%, and most were in the WHO overweight category. Clinical obesity was more prevalent in men, elderly, South Asians, and lower education or income level groups. Individuals with clinical obesity without baseline CVD had an increased hazard of incident stroke, heart failure, and myocardial infarction.

Conclusions: In a large UK cohort, preclinical and clinical obesity were common, but the risk for incident CVD was elevated for those with clinical obesity.

1 | Introduction

Obesity is a global health epidemic and a major contributor to chronic illness, morbidity, and mortality [1, 2]. Obesity is commonly defined by the World Health Organization (WHO) as a body mass index (BMI) of at least 30 kg/m² [3]. However, BMI has significant limitations in accurately assessing adiposity and its consequences at the individual level, as it does not provide

any information about lean mass, physical ability, or organ dysfunction [4, 5].

To address these concerns, the Lancet Diabetes and Endocrinology Commission (LDEC) introduced a new definition of obesity that frames it as a chronic, systemic condition with functional consequences, shifting emphasis away from BMI-based thresholds [6]. The LDEC also recommended

Study Importance

- What is already known?
 - Historically, obesity has been categorized by BMI.
 - BMI has limitations in characterizing adiposity at the individual level.
 - The Lancet Diabetes and Endocrinology Commission issued a new preclinical and clinical obesity definition to deemphasize BMI and instead prioritize the metabolic consequences of adiposity.
- What does this study add?
 - Preclinical and clinical obesity were common in individuals enrolled in the UK Biobank, especially prevalent in those previously categorized as overweight.
 - One-quarter of individuals transitioned from preclinical obesity to clinical obesity over 12 years.
 - Clinical obesity was associated with a significantly higher hazard for incident cardiovascular events compared to those with preclinical or no obesity, even at lower weight levels.
- How might these results change the direction of research or the focus of clinical practice?
 - These results suggest clinical practice should prioritize identification and treatment of those with clinical obesity as opposed to just elevated BMI.

classifying obesity into preclinical and clinical categories: clinical obesity is defined by the presence of organ dysfunction or physical limitations from excess adiposity, whereas preclinical obesity is characterized by excess fat mass without functional impairment [6]. The new definitions address two key limitations of the WHO definition—the imperfect relationship between BMI and fat mass and the consideration of clinical outcomes.

The epidemiology and public health implications of the new obesity definition are still being evaluated [7–9]. In a recent analysis of individuals in the United States, Yao et al. demonstrated that clinical obesity is highly prevalent and disproportionately represented in socioeconomically marginalized groups [10]. However, the generalizability, natural history, and cardiovascular implications of the new obesity definition are unknown [10, 11]. The objective of this study was to characterize the epidemiology of preclinical and clinical obesity in a large cohort of individuals in the United Kingdom (UK), compare similarities and differences with WHO obesity classification, and assess the risk for incident cardiovascular disease (CVD) across obesity groups.

2 | Methods

2.1 | Study Population

The UK Biobank is a large prospective cohort study in the UK, intended to investigate the genetic, environmental, and lifestyle determinants of a wide array of health outcomes [12, 13]. This study recruited over 500,000 adults aged 40–69 from 22 assessment centers across England, Scotland, and Wales from

2006 to 2010, who provided written informed consent for long-term follow-up through linkage with national health record data [12, 13]. Participants have an active, ongoing, long-term engagement with the UK Biobank, and they have regular opportunities to withdraw their consent and participation from studies [12, 13]. This study was exempt from further ethics or consent requirements.

At baseline, participants completed detailed surveys about socioeconomic demographic characteristics, health behaviors, and medical history. Participants also underwent physical measurements, imaging, and blood specimen collection for genetic and biomarker analyses. For this study, anthropometric measurements of height, weight, waist circumference (WC), hip circumference, waist-hip ratio (WHR), waist-height ratio (WHtR), BMI, and body fat percentage determined by bioimpedance from qualified nurses and health practitioners were included for 502,233 participants. Baseline blood pressure data averaged over two automated recordings and biomarker data of fasting glucose, hemoglobin A1C, low-density lipoprotein (LDL) cholesterol, high-density lipoprotein (HDL) cholesterol, and triglyceride counts were also included.

Follow-up health information was included until May 31, 2022, for Wales, August 31, 2022, for Scotland, and October 31, 2022, for England. Follow-up blood pressure and biomarker data were included when available from repeat assessments after 2012. All data were curated, quality controlled, and made available to approved researchers through the UK Biobank Research Analysis Platform.

2.2 | Definition of Preclinical and Clinical Obesity

Obesity was defined according to the LDEC criteria. Participants were defined as having obesity if they had an elevated body fat percentage ($\geq 25\%$ for males and $\geq 35\%$ for females), BMI $\geq 40 \text{ kg/m}^2$, or at least two different anthropometric measures of excess adiposity (BMI $\geq 30 \text{ kg/m}^2$; WC $\geq 88 \text{ cm}$ for females, WC $\geq 102 \text{ cm}$ for males; WHR ≥ 0.85 for females, WHR ≥ 0.90 for males; or WHtR > 0.50) [6, 14, 15]. Fat percentages were from DXA and bioelectric impedance, prioritizing DXA measurements when available.

Obesity was classified into preclinical or clinical groups depending on the presence of physical impairment or obesity-related organ dysfunction [6]. Preclinical obesity included no functional deficits, whereas clinical obesity was defined by the presence of physical impairment or at least one such obesity-related condition [6].

The clinical conditions included to classify clinical obesity were based on the recommendations from the LDEC and Yao et al. [6, 10]. The following conditions were identified using ICD-10 diagnoses and UK Biobank algorithm-derived outcomes: idiopathic intracranial hypertension (IIH), obstructive sleep apnea (OSA), pulmonary hypertension (PH), heart failure (HF), myocardial infarction (MI), stroke, atrial fibrillation (AF), deep vein thrombosis (DVT), pulmonary embolus (PE), urinary incontinence, decreased range of hip/knee movement and osteoarthritis, nonalcoholic fatty liver disease, lower limb lymphedema, anovulation, polycystic ovary syndrome, oligomenorrhea, male

hypogonadism, chronic kidney disease, type 2 diabetes (T2DM), and a metabolic disorder composite.

The metabolic disorder composite was defined as the presence of at least two of the following criteria [10]:

1. Elevated blood glucose levels: laboratory-measured fasting blood glucose > 100 mg/dL, random non-fasting blood glucose > 140 mg/dL, or hemoglobin A1C \geq 5.7%
2. Elevated blood pressure: systolic blood pressure > 140 mmHg, diastolic blood pressure > 90 mmHg, or diagnosis of primary hypertension.
3. Elevated blood triglycerides: laboratory-measured triglycerides > 150 mg/dL or diagnosis of hypertriglyceridemia.
4. Abnormal HDL cholesterol levels: laboratory-measured HDL cholesterol < 40 mg/dL for males or < 50 mg/dL for females.

Participants with physical impairment were defined as those who could not achieve 300 metabolic equivalent tasks per week, commensurate with frailty [16, 17].

2.3 | Progression From Preclinical Obesity to Clinical Obesity

Progression from preclinical to clinical obesity was defined by the development of a qualifying condition during follow-up. Cox proportional hazard models adjusted for age, sex, race, education, income, and smoking status were used to estimate the risk of incident MI, HF, and stroke. Pairwise comparisons were made between individuals with no obesity, preclinical obesity, and clinical obesity. Individuals with clinical obesity and baseline CVD were excluded from these Cox proportional hazard analyses. Additional analyses were performed to assess incident MI, HF, and stroke in individuals with clinical obesity without the metabolic disease composite as a qualifying condition. Time-to-event was defined from baseline to the first recorded event, death, or censoring.

2.4 | Statistical Analyses

The prevalence of LDEC obesity groups was stratified by WHO obesity classification, age, sex, self-reported race/ethnicity, self-reported educational attainment, and annual household income. Baseline characteristics across LDEC obesity groups were compared using Wilcoxon rank-sum tests for two-group comparisons and ANOVA for comparisons across multiple groups.

3 | Results

3.1 | Population Characteristics

The prevalence of preclinical and clinical obesity in the UK Biobank was 31.2% and 36.6%, respectively (Figure 1). The most common qualifying condition for clinical obesity was metabolic disorder (84.8%), followed by T2DM (19.6%) and musculoskeletal conditions (19.6%) (Figure 2A). Most individuals with clinical obesity had one (50.1%), two (29.4%), or three (13.2%) qualifying

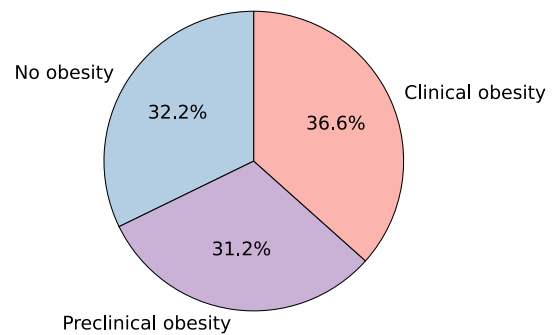


FIGURE 1 | Prevalence of no, preclinical, and clinical obesity groups as defined by LDEC in the UK Biobank.

conditions (Figure 2B). Individuals with clinical obesity on average were older and male, and had higher levels of BMI, body fat percentage, WC, systolic blood pressure, diastolic blood pressure, hemoglobin A1C, LDL, HDL, and triglyceride counts (Table 1).

Figure 3 shows the proportion of LDEC obesity groups by sociodemographic characteristics. The proportion of clinical obesity relative to preclinical or no obesity was greater in older age groups (48.2% in 65- to 70-year-olds), males (43.6%), South Asians (51.8%), individuals with secondary or lower education levels (43.3%), and participants with a household income less than 18,000 pounds (46.2%), which is the bottom 22.3% of individuals in the study. Conversely, the proportion of no obesity was greatest in younger age groups (46.9% in 40- to 45-year-olds), females (36.5%), East Asians (60.7%), individuals with university degrees (40.7%), and participants with a household income above 100,000 pounds (45.8%).

3.2 | Comparison of Lancet Commission and WHO Groups

Individuals with WHO class II and class III obesity had the greatest proportion of clinical obesity (73.5% and 79.9%, respectively) (Figure 4A). There were no individuals with WHO class I, II, or III obesity who had no obesity as defined by the LDEC. In contrast, 16.6% of normal weight and 42.3% of overweight individuals by WHO classification were reclassified as having preclinical obesity; 9.6% of normal weight and 40.6% of overweight individuals by WHO classification had clinical obesity. The most common WHO categories in those with preclinical and clinical obesity were overweight (57.3% and 46.8%, respectively) followed by WHO class I obesity (20.1% and 30.5%, respectively) (Figure 4B). A substantial proportion of individuals with preclinical or clinical obesity were normal weight as defined by the WHO (17.2% and 8.5%, respectively).

The most common qualifying condition for clinical obesity in individuals in the WHO normal weight and overweight category was metabolic disorder (77.4% and 83.2%, respectively) (Figure S1). The second most common qualifying condition for clinical obesity was physical limitation (16.8%) for individuals in the WHO normal weight category and musculoskeletal conditions (16.9%) for those in the WHO overweight category (Figure S1). Individuals with clinical obesity in the WHO obesity group had significantly more qualifying conditions for clinical obesity (2.1 ± 1.2) than those in the WHO overweight (1.7 ± 0.9) or normal weight groups (1.5 ± 0.8) (H-statistic 6829, $p < 0.001$).

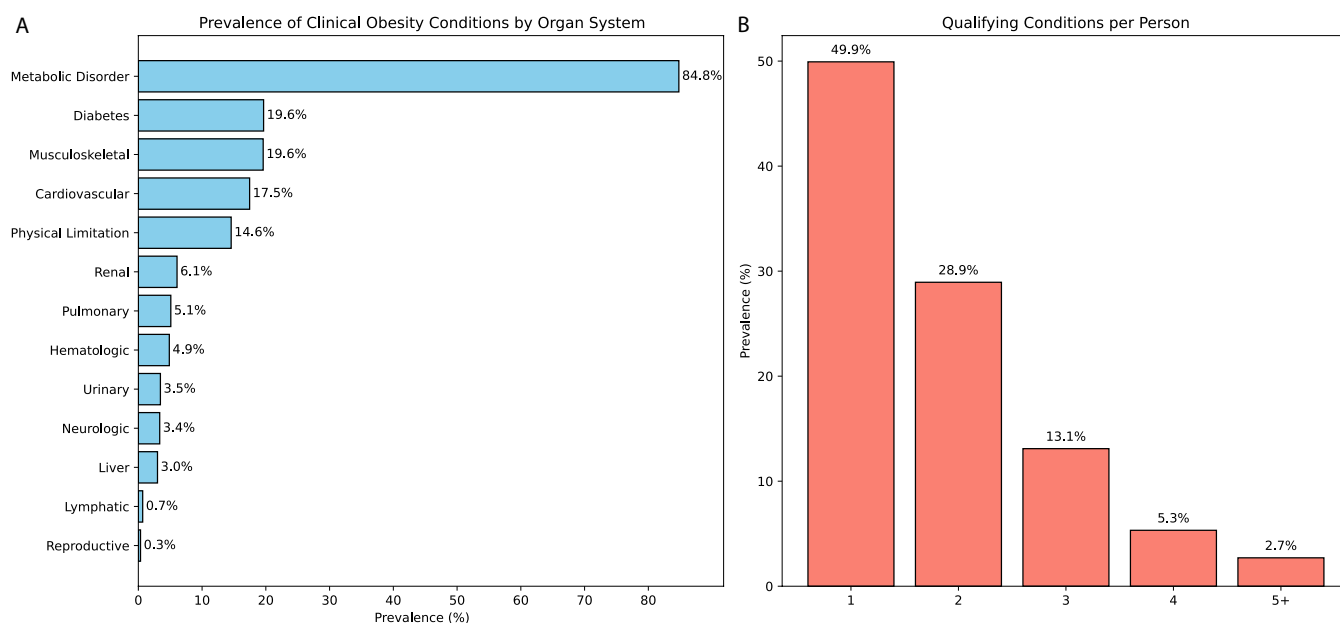


FIGURE 2 | (A) Prevalence of qualifying conditions for clinical obesity grouped by organ system and (B) number of qualifying conditions for everyone with clinical obesity in the UK Biobank.

TABLE 1 | Baseline characteristics for individuals with no, preclinical, and clinical obesity.

	No obesity	Preclinical obesity	Clinical obesity
Age (years)	54.6 ± 8.3	56.3 ± 8.0	58.5 ± 7.6
Male (%)	38%	43%	54%
BMI (kg/m ²)	23.3 ± 2.3	28.3 ± 3.8	30.3 ± 4.7
Body fat (%)	25.6 ± 6.5	33.9 ± 7.9	34.4 ± 8.1
Waist circumference (cm)	78.3 ± 8.2	92.4 ± 10.4	99.0 ± 11.8
Systolic BP (mmHg)	132.6 ± 18.5	135.7 ± 17.6	144.1 ± 17.9
Diastolic BP (mmHg)	78.8 ± 9.8	81.9 ± 9.4	85.4 ± 10.1
A1C (%)	5.3 ± 0.5	5.3 ± 0.3	5.7 ± 0.8
LDL (mg/dL)	133.5 ± 31.1	140.7 ± 32.0	138.5 ± 36.5
HDL (mg/dL)	62.1 ± 15.3	59.1 ± 13.1	48.5 ± 12.1
Triglycerides (mg/dL)	118.1 ± 64.9	127.5 ± 62.6	207.5 ± 103.3

Note: Data given as mean ± SD.

The socioeconomic demographics of individuals with the WHO normal weight and overweight categories are shown in Figures S2 and S3, respectively. For individuals in the WHO normal weight or overweight categories, the proportion of clinical obesity was the largest in older age groups, males, South Asians, individuals with secondary or lower education levels, and participants with a lower annual household income.

3.3 | Longitudinal Outcomes of Preclinical and Clinical Obesity

Figure 5 shows the survival curves of time-to-transition from preclinical to clinical obesity; 24.1% of individuals with

preclinical obesity transitioned to clinical obesity within 12 years of follow-up. The median duration of preclinical obesity in those who transitioned to clinical obesity from the time of enrollment and baseline assessment in the UK Biobank was 7.4 years. Among individuals who had repeat anthropometric measurement assessments, there were 2.0% of those with preclinical obesity who transitioned to no obesity.

Individuals with clinical obesity had an increased hazard of incident stroke (hazard ratio [HR] 1.51, CI 1.43–1.60), HF (HR 2.16, CI 2.07–2.25), and MI (HR 1.82, CI 1.73–1.91) compared to those without obesity after adjusting for age, sex, ethnicity, education, income, and smoking (Figure 6A), which was significantly greater than the hazard of incident events for those

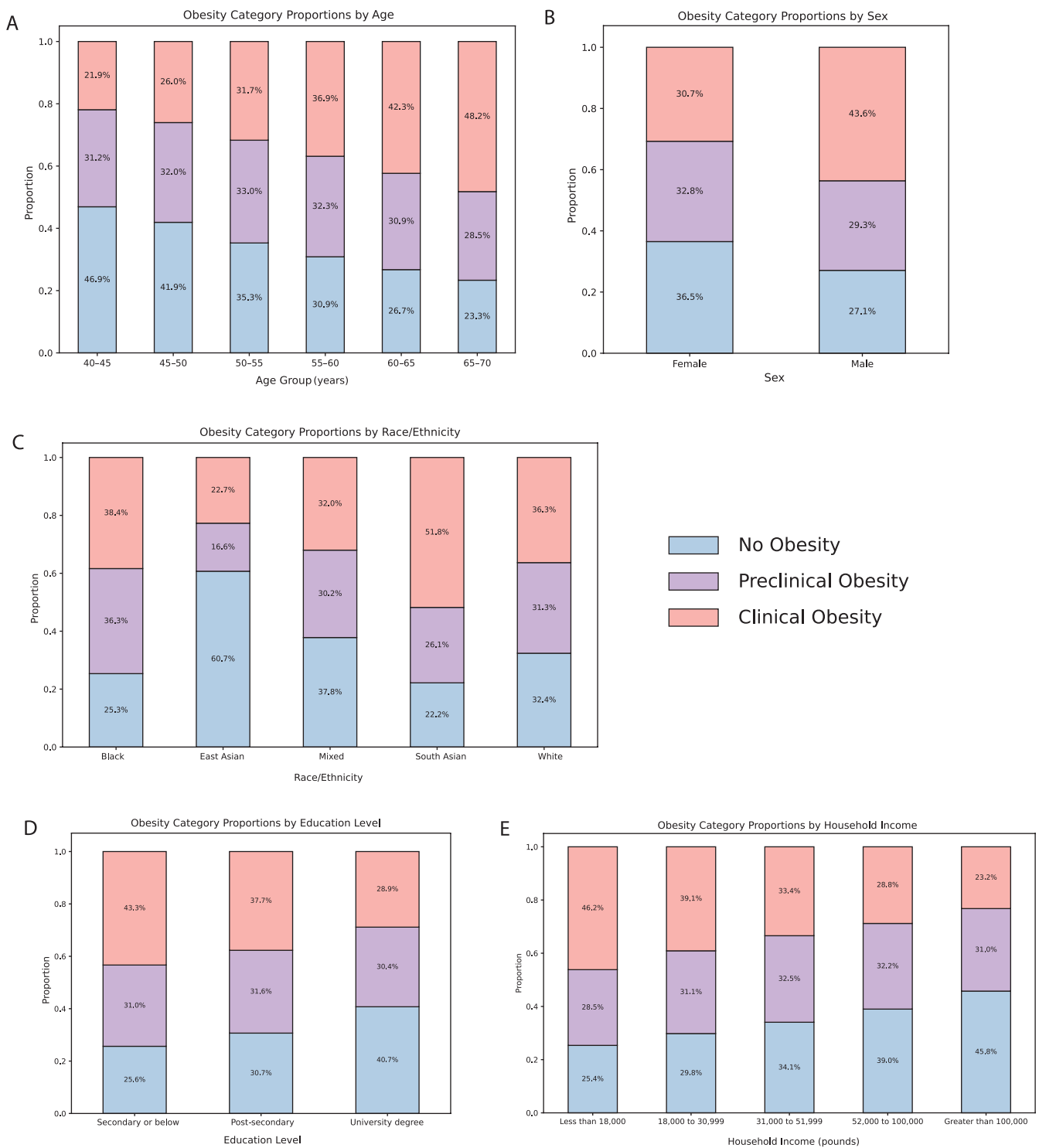


FIGURE 3 | Proportion of no, preclinical, and clinical obesity by (A) age, (B) sex, (C) self-identified race/ethnicity, (D) educational attainment, and (E) household income before taxes.

with preclinical obesity compared to no obesity (stroke HR 0.99, CI 0.93–1.05; HF HR 1.12, CI 1.07–1.18; and MI HR 1.09, CI 1.03–1.15). Participants with clinical obesity all had significantly elevated hazards for incident stroke, HF, and MI across WHO normal weight, overweight, and obesity category groups compared to those without obesity (Figure 6B). Participants with clinical obesity in the WHO obesity group had the greatest overall hazard (Table 2). There was no meaningful difference

in C-statistic, calibration, or reclassification between LDEC and WHO groups for prediction of incident stroke, HF, or MI after adjustment for age, sex, ethnicity, income, and smoking (Table S1).

Since the metabolic disease composite includes established CVD risk factors and was the most common qualifying condition for clinical obesity, we evaluated the hazard for incident

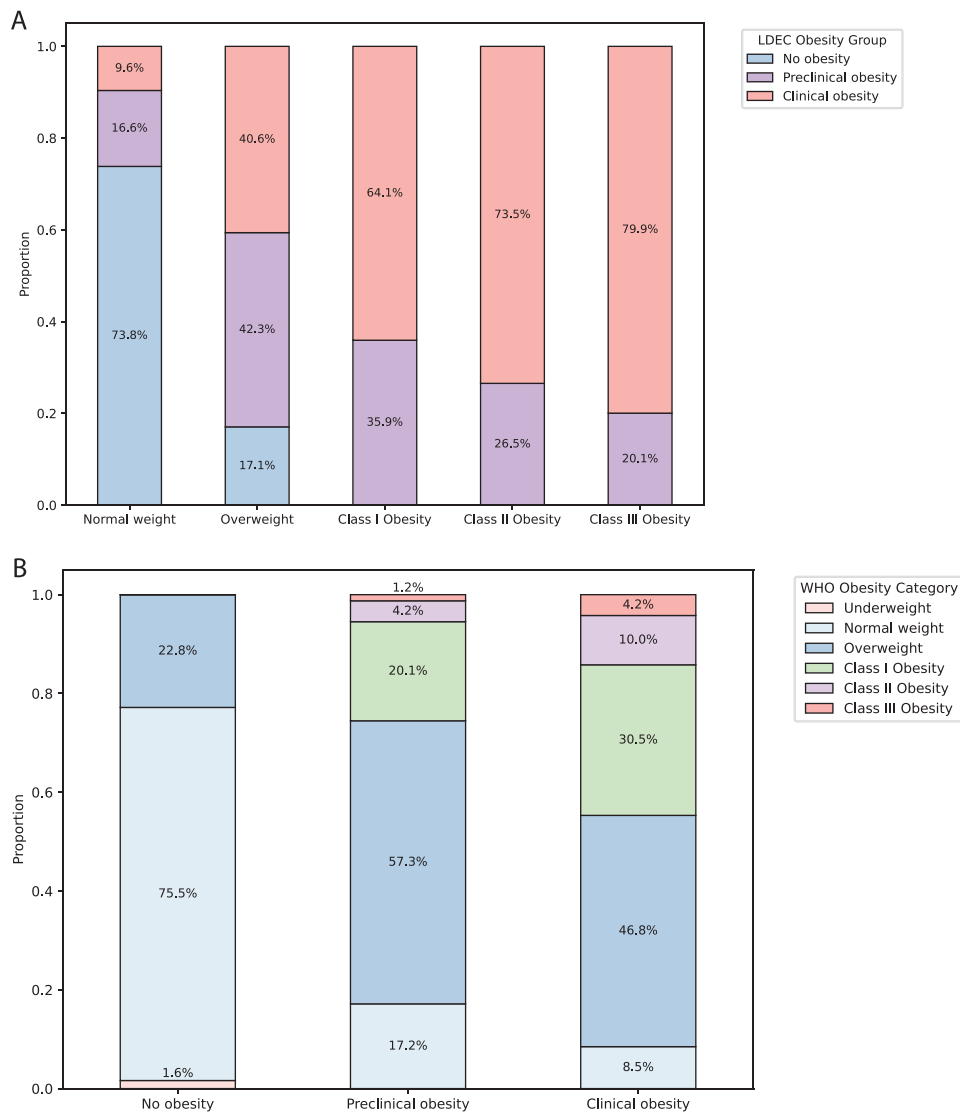


FIGURE 4 | (A) Prevalence of LDEC obesity groups by WHO obesity category. (B) Prevalence of WHO obesity categories in each LDEC obesity group.

CVD in individuals with clinical obesity excluding this group. Individuals with clinical obesity without baseline metabolic disease had an increased hazard of stroke (HR 1.54, CI 1.39–1.68), HF (HR 2.72, CI 2.54–2.91), and MI (HR 1.53, CI 1.40–1.68) compared to those without obesity after adjusting for age, sex, ethnicity, education, income, and smoking, which was consistent across all WHO categories (Figure S4).

4 | Discussion

In this study within the UK Biobank, we evaluated the prevalence, socioeconomic distribution, comparison with WHO obesity groups, and clinical consequences of preclinical and clinical obesity as defined by the LDEC. We found that:

1. Preclinical and clinical obesity were common with a 31.2% and 36.6% prevalence.
2. The proportion of clinical obesity was greater in the elderly, men, South Asians, and individuals with lower income and educational attainment.

3. Preclinical and clinical obesity were prevalent in those in the WHO overweight category (57.3% and 46.8%, respectively).
4. One-quarter of individuals transitioned from preclinical to clinical obesity over 12 years.
5. Individuals with clinical obesity had a significantly greater hazard of incident CVD events compared to those with preclinical or no obesity.

Obesity has traditionally been defined using BMI thresholds by the WHO, but this approach can misrepresent the impact of adiposity at the individual level as it does not incorporate lean muscle mass, physical fitness, or clinical characteristics [4–6, 11]. In 2025, the LDEC proposed a new definition to integrate other measurements of excess fat mass and shift focus away from BMI [6, 11]. This reclassification has sparked debate, as some critics argue this definition could complicate decision-making, increase discrimination and bias, and reduce coverage for obesity treatment [18–20]. We found that 67.8% of individuals in the UK Biobank had obesity using the LDEC criteria, similar to the prevalence of 68.0% of individuals in the All of

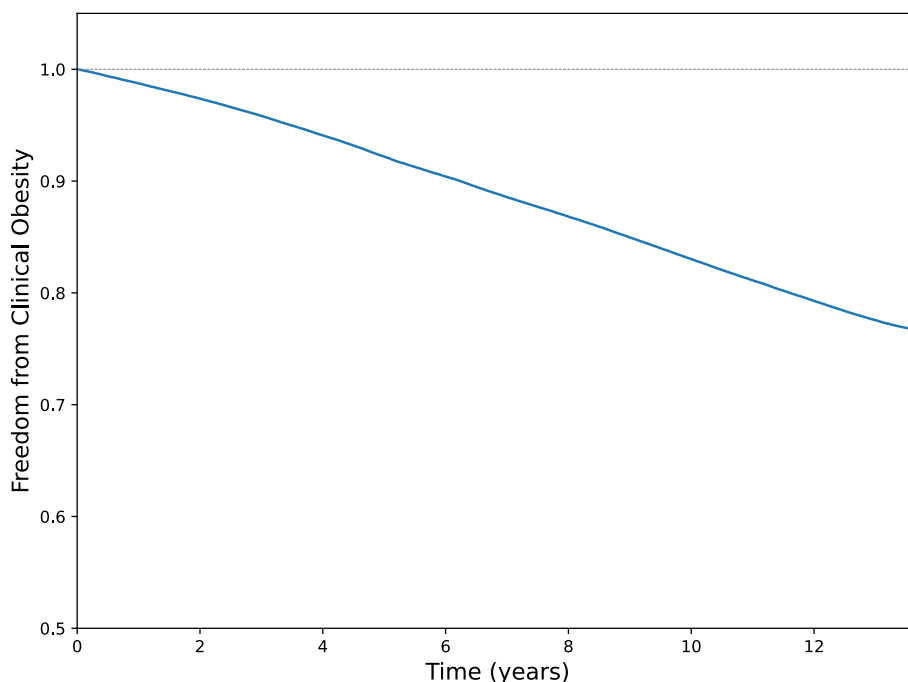


FIGURE 5 | Survival curve of freedom from clinical obesity for individuals with preclinical obesity at baseline enrollment.

Us Research Program [21]. This large prevalence is substantially greater than the estimated 29% of individuals with obesity by the WHO criteria in the UK [22] and it is larger in marginalized sociodemographic groups [23]. In our study, there was a substantial proportion of individuals in the WHO overweight or normal weight categories who were upgraded to preclinical and clinical obesity, but no one in the WHO obesity categories who was downgraded to no obesity by the LDEC criteria.

In our study, we found that LDEC classification did not provide significant discrimination over WHO classification at a global level, but individuals with clinical obesity in the WHO normal weight or overweight categories still had a significantly increased hazard for incident CVD events. Individuals in these specific categories were more frequently from South Asian ancestry, lower socioeconomic status, and older age, groups in whom the metabolic consequences of adiposity occur at lower BMI levels and are less recognized in clinical practice [24–26]. Thus, LDEC classification may possibly improve obesity recognition and risk prognosis in these specific groups. Further investigation is needed to determine the best therapeutic strategy for individuals with metabolic dysfunction and adiposity in the WHO normal weight and overweight categories, who are often excluded from obesity clinical management trials [27]. Additionally, further work is needed to improve the performance of overall CVD risk prediction in individuals with obesity. Recent consensus statements have recommended implementation of obesity staging systems to characterize the severity of obesity-related diseases and complications, but epidemiological and clinical studies are needed to evaluate whether they add meaningful discrimination or clinical utility.

The LDEC recommended stratifying individuals with obesity into preclinical or clinical groups depending on the presence of physical limitations or obesity-related organ dysfunction [6].

For those with preclinical obesity, the LDEC recommended focusing on risk reduction and progression to clinical obesity with health counseling, serial monitoring, and active weight loss interventions [6]. Critics comment that this proposed strategy has the potential to delay crucial early interventions, increase health risks, and worsen long-term health outcomes [18–20]. However, we find that individuals with preclinical obesity in the UK Biobank had a low hazard for incident CVD events and had a slow and modest transition to clinical obesity within 12 years. These observations support the strategy of active surveillance recommended by the LDEC, with prioritization of aggressive evidence-based treatment for those with clinical obesity [6].

In our study, individuals with clinical obesity had a substantially increased hazard for incident stroke, MI, and HF. The most common qualifying condition for clinical obesity was a metabolic composite of prediabetes, hypertension, and dyslipidemia, reinforcing the importance of aggressive risk factor control to improve life expectancy and reduce CVD events [28]. However, individuals without this metabolic disease composite still had an increased hazard for CVD events, suggesting that identifying individuals with clinical obesity status may add prognostic value beyond canonical risk factors. This observation highlights the importance of performing a comprehensive history, examination, and studies to diagnose obesity complications, which are often underreported by patients and underrecognized by clinicians.

Nonetheless, the practical application of the LDEC obesity definitions in routine management remains unclear [11]. Yao et al. previously described that there is variability in obesity classification depending on the criteria used to describe physical impairment or metabolic disorder [10]. Since publication, the LDEC obesity definition has sparked debate about how best to characterize adiposity, the anthropometric and body fat measurements for obesity diagnosis, the utility of imaging, the

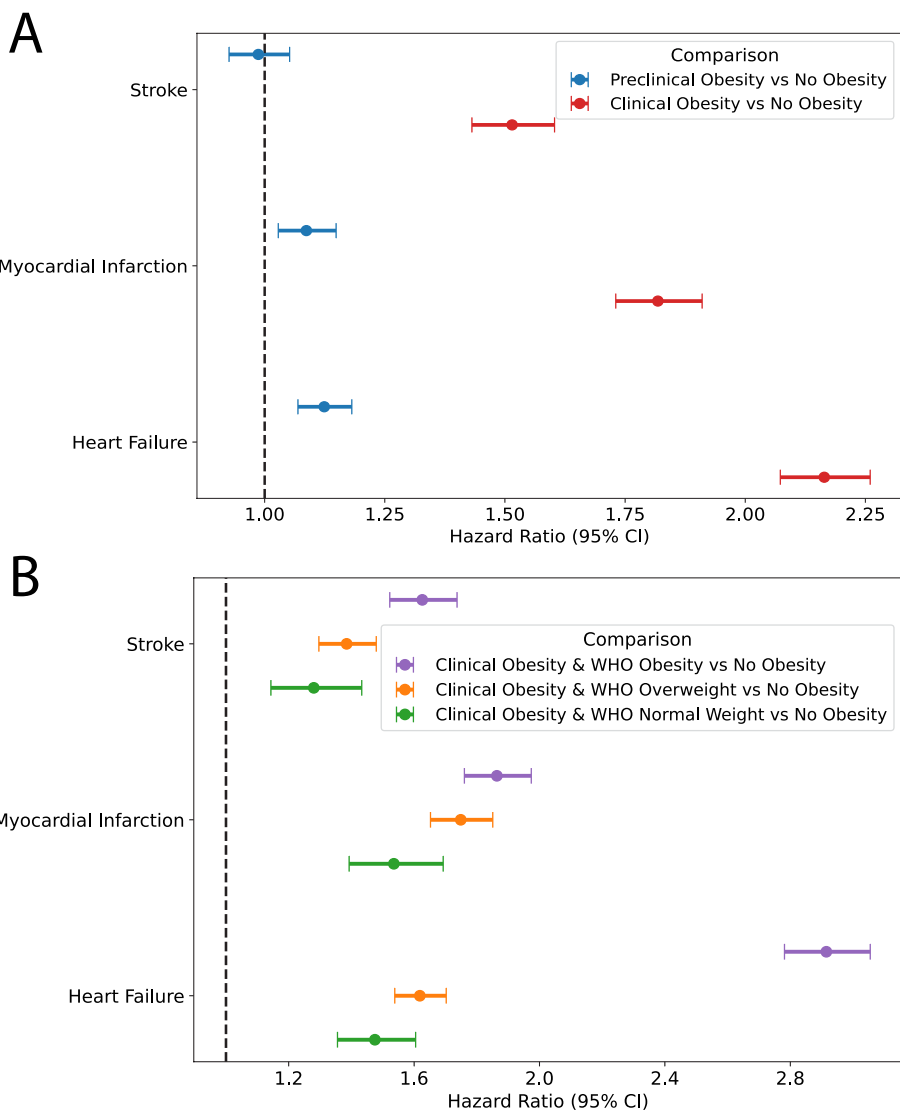


FIGURE 6 | Hazard ratio of stroke, heart failure, and myocardial infarction for (A) individuals with preclinical obesity and individuals with clinical obesity without baseline cardiovascular disease and (B) individuals with WHO normal weight, overweight, and obesity and clinical obesity without baseline cardiovascular disease.

qualifying conditions for clinical obesity, and the practical utility given insurance barriers to obesity treatment [7–9, 29–32]. Our intention was to translate the LDEC conceptual model as plainly written into a reproducible and scalable classification for population-level research. The LDEC acknowledges that its criteria have limitations but states its intentions were to reduce the mischaracterization of obesity at the individual level. However, this ambiguity and controversy create challenges for policy development, clinical decision pathways, or obesity management trials. Although BMI is an imperfect measure of adiposity, it is easily measured, widely understood, and commonly adopted in clinical guidelines [4, 5]. Standardized guidelines with explicit recommendations are needed to ensure consistency and increase adoption of the LDEC obesity definition.

Our study has several limitations, and the results should be interpreted with caution. The use of electronic health records and ICD-10 diagnosis codes to classify obesity complications has the potential to mischaracterize preclinical and clinical obesity [33, 34]. Individuals without a known qualifying diagnosis

for clinical obesity may have disease at baseline but without a corresponding ICD-10 diagnosis, which can possibly underreport the prevalence of clinical obesity at baseline and inflate the hazard of incident CVD events. Additionally, our analysis relied on longitudinal health record data and volunteers who returned for additional testing as opposed to systematic screening, which has the potential to underreport the incidence of clinical obesity on follow-up [35]. Our analyses did not address time-varying exposure, frequency of surveillance, or competing risk of death, which likely underappreciates the transition to clinical obesity in follow-up. Moreover, the inclusion of organ dysfunction and physical limitation for the diagnosis of clinical obesity raises concerns when evaluating associations with disease risk as obesity-related causality cannot be inferred, reverse causation is probable, obesity severity is not addressed, and discriminating the impact of obesity from traditional risk factors is challenging. These limitations are in part a broader societal problem with the management of obesity, in which individuals experience weight-related stigma in clinical settings and daily life. Consequently, diagnoses of obesity complications are

TABLE 2 | Hazard ratios of incident heart failure, myocardial infarction, and stroke for various obesity groups stratified by Lancet Commission and WHO categories relative to no obesity, adjusted for age, sex, ethnicity, education, income, and smoking.

Condition	Group	Hazard ratio	95% CI
Heart failure	Preclinical obesity	1.12	[1.07–1.18]
	Clinical obesity	2.16	[2.07–2.26]
	Clinical obesity & WHO obesity	2.91	[2.78–3.05]
	Clinical obesity & WHO overweight	1.62	[1.54–1.70]
	Clinical obesity & WHO normal weight	1.47	[1.36–1.60]
Myocardial infarction	Preclinical obesity	1.09	[1.03–1.15]
	Clinical obesity	1.82	[1.73–1.91]
	Clinical obesity & WHO obesity	1.86	[1.76–1.97]
	Clinical obesity & WHO overweight	1.75	[1.65–1.85]
	Clinical obesity & WHO normal weight	1.54	[1.39–1.69]
Stroke	Preclinical obesity	0.99	[0.93–1.05]
	Clinical obesity	1.51	[1.43–1.60]
	Clinical obesity & WHO obesity	1.63	[1.52–1.74]
	Clinical obesity & WHO overweight	1.38	[1.30–1.48]
	Clinical obesity & WHO normal weight	1.28	[1.14–1.43]

Note: Individuals with baseline cardiovascular disease were excluded from the clinical obesity groups. The significance values are all less than 0.001 (in bold).

underreported, therapeutic management is delayed, and clinical equity is exacerbated [34, 35]. Finally, significant criticism of the UK Biobank includes the lack of ethnic and socioeconomic diversity, lack of adjudication, and lack of regularized follow-up, all of which raise concerns about the generalizability of our findings to other populations or underserved individuals [36]. Because of these limitations, we recommend further investigation of the LDEC definition in other large-scale epidemiological cohorts and integration into clinical workflows in order to assess whether we can reduce further stigma, bias, and inequities in obesity [7–9].

5 | Conclusion

Preclinical and clinical obesity were common in the UK Biobank and prevalent in individuals in the WHO overweight category.

One-quarter of individuals transitioned from preclinical to clinical obesity over 12 years. Clinical obesity was associated with a significantly higher risk for incident CVD events compared to preclinical or no obesity. Further work is needed to assess whether implementation of the LDEC obesity definition impacts clinical outcomes.

Author Contributions

S.Z., Z.Y., S.N.J., A.K., and A.W.P. performed data analyses and helped write and revise the original drafts. R.S.B., M.A., A.B., and M.J.B. supervised the project, provided resources, and helped revise the manuscript.

Funding

The authors have nothing to report.

Conflicts of Interest

Michael Blaha received consulting fees from Agepha, Amgen, AstraZeneca, Bayer, Boehringer Ingelheim, Eli Lilly and Company, Genentech, Merck, Novo Nordisk, Roche, Vectura Limited; research grants to Johns Hopkins University from Amgen, Bayer, and Novo Nordisk; and end point review committee membership from Abbott Laboratories and Siemens. Alexis Battle is a cofounder and equity holder of CellCipher Inc., has consulted for Third Rock Ventures, and is a stockholder of Alphabet Inc. None of these companies were involved with or influenced this manuscript. The other authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from UK Biobank. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the author(s) with the permission of UK Biobank.

References

- GBD 2015 Obesity Collaborators, A. Afshin, M. H. Forouzanfar, et al., “Health Effects of Overweight and Obesity in 195 Countries Over 25 Years,” *New England Journal of Medicine* 377 (2017): 13–27.
- GBD 2021 Adult BMI Collaborators, “Global, Regional, and National Prevalence of Adult Overweight and Obesity, 1990–2021, With Forecasts to 2050: A Forecasting Study for the Global Burden of Disease Study 2021,” *Lancet* 405 (2025): 813–838.
- World Health Organization, “Obesity: Preventing and Managing the Global Epidemic. Report of a WHO Consultation,” *World Health Organization Technical Report Series* 894 (2000): 1–253.
- K. Sweatt, W. T. Garvey, and C. Martins, “Strengths and Limitations of BMI in the Diagnosis of Obesity: What Is the Path Forward?,” *Current Obesity Reports* 13 (2024): 584–595.
- Y. Wu, D. Li, and S. H. Vermund, “Advantages and Limitations of the Body Mass Index (BMI) to Assess Adult Obesity,” *International Journal of Environmental Research and Public Health* 21 (2024): 757.
- F. Rubino, D. E. Cummings, R. H. Eckel, et al., “Definition and Diagnostic Criteria of Clinical Obesity,” *Lancet Diabetes and Endocrinology* 13 (2025): 221–262.
- Y. Shen and G. Hu, “Prevalence of Clinical Obesity in US Adults, 2017–2020,” *Obesity (Silver Spring)* 33 (2025): 1968–1976.
- M. Xu, M. Li, Y. Zhang, L. Li, Y. Shen, and G. Hu, “Dynamic Phenotypes of Preclinical and Clinical Obesity in Relation to New-Onset Cancer Risk: A Longitudinal Analysis From the UK Biobank,” *Diabetes, Obesity & Metabolism* 27 (2025): 5291–5301.

9. M. Xu, M. Li, Y. Zhang, L. Li, Y. Shen, and G. Hu, "Contributions of Clinical Obesity and Preclinical Obesity to the all-Cause Mortality Risk: Findings From the UK Biobank Cohort," *Diabetes/Metabolism Research and Reviews* 41 (2025): e70095.
10. Z. Yao, Z. A. Dardari, A. C. Razavi, et al., "The New Clinical Obesity Definition: An Evaluation of Prevalence Versus the WHO Definition of Obesity Among US Adults," *Lancet Diabetes and Endocrinology* 13 (2025): 647–649.
11. The Lancet Diabetes Endocrinology Commission, "Redefining Obesity: Advancing Care for Better Lives," *Lancet Diabetes & Endocrinology* 13 (2025): 75.
12. C. Bycroft, C. Freeman, D. Petkova, et al., "The UK Biobank Resource With Deep Phenotyping and Genomic Data," *Nature* 562 (2018): 203–209.
13. N. Allen, C. Sudlow, P. Downey, et al., "UK Biobank: Current Status and What It Means for Epidemiology," *Health Policy and Technology* 1 (2012): 123–126.
14. World Health Organization, "Physical Status: The Use and Interpretation of Anthropometry. Report of a WHO Expert Committee," *World Health Organization Technical Report Series* 854 (1995): 1–452.
15. P. Deurenberg, M. Yap, and W. A. van Staveren, "Body Mass Index and Percent Body Fat: A Meta Analysis Among Different Ethnic Groups," *International Journal of Obesity and Related Metabolic Disorders* 22 (1998): 1164–1171.
16. F. C. Bull, S. S. Al-Ansari, S. Biddle, et al., "World Health Organization 2020 Guidelines on Physical Activity and Sedentary Behaviour," *British Journal of Sports Medicine* 54 (2020): 1451–1462.
17. L. P. Fried, C. M. Tangen, J. Walston, et al., "Frailty in Older Adults: Evidence for a Phenotype," *Journals of Gerontology Series A: Biological Sciences and Medical Sciences* 56 (2001): M146–M157.
18. R. Dalle Grave, "From Division to Dialogue: Uniting Paradigms to Advance Obesity and Eating Disorder Treatment," *IJEDO* 7 (2025): 31–40.
19. J. Bowman-Busato, L. Schreurs, J. C. Halford, et al., "Providing a Common Language for Obesity: The European Association for the Study of Obesity Obesity Taxonomy," *International Journal of Obesity (Lond)* 49 (2025): 182–191.
20. European Association for the Study of Obesity, "EASO Response to the Lancet Commission Report on Obesity Diagnosis and Management," published January 24, 2025, <https://easo.org/easo-response-to-the-lancet-commission-report-on-obesity-diagnosis-and-management/>.
21. Z. Yao, Z. A. Dardari, A. C. Razavi, et al., "Prevalence of Clinical Obesity Versus BMI-defined Obesity Among US Adults: A Cohort Study," *Lancet Diabetes and Endocrinology* 13 (2025): 647–649, [https://doi.org/10.1016/S2213-8587\(25\)00159-7](https://doi.org/10.1016/S2213-8587(25)00159-7).
22. Health Survey for England, "Adult Overweight and Obesity," NHS England, published September 24, 2024, <https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-for-england/2022-part-2/adult-overweight-and-obesity>.
23. A. M. El-Sayed, P. Scarborough, and S. Galea, "Unevenly Distributed: A Systematic Review of the Health Literature About Socioeconomic Inequalities in Adult Obesity in the United Kingdom," *BMC Public Health* 12 (2012): 18, <https://doi.org/10.1186/1471-2458-12-18>.
24. B. Ohlsson and J. Manjer, "Sociodemographic and Lifestyle Factors in Relation to Overweight Defined by BMI and "Normal-Weight Obesity"," *Journal of Obesity* 2020 (2020): 2070297.
25. L. P. Franco, C. C. Morais, and C. Cominetti, "Normal-Weight Obesity Syndrome: Diagnosis, Prevalence, and Clinical Implications," *Nutrition Reviews* 74 (2016): 558–570.
26. M. Riaz and S. Lodhi, "Beyond BMI: Exploring Obesity Trends in the South Asian Region," *Obesity Pillars* 13 (2024): 100156.
27. N. N. Wijayatunga and E. J. Dhurandhar, "Normal Weight Obesity and Unaddressed Cardiometabolic Health Risk—A Narrative Review," *International Journal of Obesity (Lond)* 45 (2021): 2141–2155.
28. Global Cardiovascular Risk Consortium, C. Magnussen, J. Alegre-Diaz, et al., "Global Effect of Cardiovascular Risk Factors on Lifetime Estimates," *New England Journal of Medicine* 393 (2025): 125–138.
29. F. Rubino, W. A. Brown, P. R. Schauer, F. Pattou, and R. V. Cohen, "From BMI to Disease Diagnosis: What Clinical and Pre-Clinical Obesity Mean for Surgeons," *Obesity Surgery* 35 (2025): 4559–4564.
30. E. K. Aryee, S. Zhang, E. Selvin, and M. Fang, "Prevalence of Obesity With and Without Confirmation of Excess Adiposity Among US Adults," *JAMA* 333 (2025): 1726–1728.
31. T. Guo, P. He, W. Lu, et al., "Visceral Adiposity Thresholds for Cardiovascular Risk Stratification: A Simplified Biomarker-Driven Model," *Obesity (Silver Spring)* 33 (2025): 2005–2013.
32. H. S. J. Chew, M. Dalakoti, M. K. S. Leow, L. Sun, J. H. C. Ang, and R. Foo, "Waist Circumference Remains the Better Predictor of Insulin Resistance Compared to 2025 Lancet Commission Definition on Clinical Obesity," *Diabetes, Obesity & Metabolism* 27 (2025): 6775–6778.
33. J. Stausberg, N. Lehmann, D. Kaczmarek, and M. Stein, "Reliability of Diagnoses Coding With ICD-10," *International Journal of Medical Informatics* 77 (2008): 50–57.
34. A. Kapoor, J. Kim, X. Zeng, S. T. Harris, and A. Anderson, "Weighing the Odds: Assessing Underdiagnosis of Adult Obesity via Electronic Medical Record Problem List Omissions," *Digital Health* 6 (2020): 2055207620918715.
35. J. Ma, L. Xiao, and R. S. Stafford, "Underdiagnosis of Obesity in Adults in US Outpatient Settings," *Archives of Internal Medicine* 169 (2009): 312–316.
36. A. Fry, T. J. Littlejohns, C. Sudlow, et al., "Comparison of Socio-demographic and Health-Related Characteristics of UK Biobank Participants With Those of the General Population," *American Journal of Epidemiology* 186 (2017): 1026–1034.

Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Figure S1:** Prevalence and number of qualifying conditions for clinical obesity grouped by organ system in individuals in WHO normal weight, overweight, or obesity groups. **Figure S2:** Proportion of no, preclinical, and clinical obesity across (A) age groups, (B) sex, (C) self-identified race/ethnicity, (D) educational attainment, and (E) household income before taxes for individuals in the WHO normal weight category. **Figure S3:** Proportion of no, preclinical, and clinical obesity across (A) age groups, (B) sex, (C) self-identified race/ethnicity, (D) educational attainment, and (E) household income before taxes for individuals in the WHO overweight category. **Figure S4:** Hazard ratio of stroke, heart failure, and myocardial infarction for individuals with A) preclinical obesity and individuals with clinical obesity without baseline cardiovascular disease or metabolic disease composite and B) individuals with WHO normal weight, overweight, and obesity and clinical obesity without baseline cardiovascular disease or metabolic disease composite. **Data S1:** oby70126-sup-0005-Tables.xlsx.