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Ten-year progression of obesity-related complications in a population with overweight and obesity in the UK: A retrospective open cohort study

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Abstract

Aim: To assess the prevalence of individual obesity-related complications (ORCs) and multimorbidity (≥ 1, ≥ 2 and ≥ 3 ORCs), and multimorbidity-associated healthcare costs, over 10 years.

Methods: This retrospective open cohort study used Discover, a UK database of linked primary and secondary electronic health records. Adults were stratified by body mass index (BMI; overweight: 25-< 30 kg/m^2; obesity class I: 30-< 35 kg/m^2; obesity class II: 35-< 40 kg/m^2; obesity class III: ≥ 40 kg/m^2). Outcomes by year since baseline were assessed for serial cross sections across the study period (1 January 2004 to 31 December 2019; the index date was the date of first eligible BMI measurement).

Results: Across 1 410 146 individuals (overweight: 1 008 101; obesity class I: 278 782; obesity class II: 80 621; obesity class III: 42 642), ORC prevalence was higher in successive BMI groups, and increases over time were generally greater for obesity relative to overweight. In those with ORC multimorbidity, both higher BMI and the presence of more ORCs were associated with higher annual per-person healthcare costs. Costs increased over time in those individuals with obesity and one or more ORC, as well as in those with obesity and two or more ORCs.

Conclusions: Higher BMI was associated with higher baseline ORC prevalence and a greater increase in ORC prevalence over time, and with higher healthcare costs in those with multimorbidity. To reduce the burden of overweight and obesity on patients and healthcare systems, the presence, number and type of ORCs should be considered in developing effective, targeted prevention and management care pathways.

KEYWORDS
cohort study, database research, observational study, population study, real-world evidence

1 | INTRODUCTION

High body mass index (BMI), defined as overweight (BMI 25-< 30 kg/m^2) and obesity (BMI ≥ 30 kg/m^2), is associated with a range of other chronic conditions.[1] For example, individuals living with obesity are more than seven times more probable to develop type 2 diabetes (T2D)[2] and almost twice as probable to develop cardiovascular disease (CVD) than people with healthy weight.[3] Accordingly, reducing the risk of co-morbidity development is a focus of obesity-management strategies and treatment decision-making, including in the UK National Institute for Health and Care Excellence (NICE) guidelines.[4]

The high prevalence of obesity-related complications (ORCs) has been shown in recent analyses: in a US cohort with obesity, approximately one-third had two or more ORCs.[5] Consequently, many individuals living with obesity are considered to have multimorbidity, which is defined as the presence of two or more long-term health conditions,[6] and obesity is widely considered an important modifiable risk factor for multimorbidity.[7]

The World Obesity Atlas, published in early 2023, suggests that the global economic impact of overweight and obesity could reach $4.32 trillion annually by 2035.[8] Multimorbidity is also associated with considerable healthcare demand and healthcare resource utilization (HCRU).[9,10] ORCs are therefore a contributor towards costs in obesity: in a recent study, total healthcare costs were universally higher in people living with obesity who had at least one of 11 co-morbidities, compared with those who had obesity but no co-morbidities.[11]

Characterization of trends in ORC and ORC multimorbidity prevalence, and corresponding healthcare costs, in people living with overweight or obesity are needed to obtain insights to inform healthcare planning and preventive efforts. In this study, we aimed to quantify the progression of various ORCs, ORC multimorbidity (≥ 1, ≥ 2 and ≥ 3 ORCs) and multimorbidity-associated healthcare costs in those living with overweight and obesity over time.

2 | MATERIALS AND METHODS

This retrospective open cohort study used data from the Discover database to estimate the prevalence of ORCs and multimorbidity, and associated healthcare costs in those with multimorbidity, over a period of 10 years in a real-world population with overweight and obesity.

2.1 | Data sources

Discover is a real-world database of linked primary and secondary electronic health records covering 2.7 million people residing in North West London, accounting for more than 95% of the North West London population.[12,13] The database is linked to the Whole Systems Integrated Care database, which was developed for commissioning and direct patient care across North West London.[12] Pseudo-anonymized patient-level data are available for research through an application process via the North West London Information Governance Steering Group. Primary care data are available from 1 January 2004 onwards, with linkage to secondary care data available from 1 January 2015.

The presence of ORCs was determined from primary or secondary care records using International Classification of Diseases, 10th Revision (ICD-10) codes, Office of Population Censuses and Surveys 4th revision codes and Read codes for primary care data. For secondary care data, prevalent co-morbidities were identified using both primary and secondary diagnostic codes from hospital stays. The ICD-10 codes for each condition included in the analysis are listed in the supporting information (Table S1).

2.2 | Study design and population

Individuals aged at least 18 years with known sex and eligible BMI records (either directly recorded or calculated based on height and weight) were stratified according to BMI at baseline: overweight (25-< 30 kg/m^2), obesity class I (30-< 35 kg/m^2), obesity class II (35-< 40 kg/m^2) and obesity class III (≥ 40 kg/m^2).

Individuals were assessed on 1 January of each year using the most recent BMI measurement, and could remain in the same BMI group, transition to a different group, or enter an inactive group if their BMI was less than 25 kg/m^2 or there was no BMI measurement in the previous 3 years. Individuals in the inactive group were assessed with the rest of the study population on 1 January of each year, and could re-enter the analysis if the relevant criteria were met.

The study period was 1 January 2004 to 31 December 2019, although outcomes involving secondary care data, such as healthcare costs, were limited to the period 2015 to 2019. The index date was the date of first eligible BMI measurement in each BMI group in the study period, and individuals were followed for up to 10 years until month of death, transfer-out date from the North-West London region, or end of study period, whichever was earliest. In all groups, individuals with no records of general practitioner (GP) visits for more than 5 years during follow-up were excluded.

Outcomes were analysed over a duration time perspective whereby individuals were identified according to their first BMI measurement and followed up for up to 10 years. Therefore, outcomes by year since baseline were assessed for serial cross sections across the study period, with individuals in that year of their total duration of follow-up, regardless of index date. Prevalence estimates were calculated using only individuals who were active mid-year across the whole study period (2004-2019). Cost estimates used the sum of person time contributed by all individuals featured in the cross section from 2015 to 2019. Although data are available in Discover up to 2022, the study followed up patients until 2019 to exclude healthcare data from the period during which healthcare systems were disrupted by the COVID-19 pandemic.

2.3 | Outcomes

Outcomes were the prevalence of individual ORCs and multimorbidity, and healthcare costs in groups with multimorbidity. All outcomes were analysed separately for those with overweight and obesity class I, II and III.

The following conditions of key interest were included in the individual ORCs analysis: atherosclerotic cardiovascular disease (ASCVD) including cerebrovascular disease, ischaemic heart disease and peripheral artery disease, atrial fibrillation, chronic kidney disease (CKD) stage 3-5, depression, heart failure, hypertension, knee osteoarthritis (KOA), obstructive sleep apnoea (OSA), prediabetes and T2D.

Co-morbidities considered when defining groups with multimorbidity were ASCVD (including cerebrovascular disease, ischaemic heart disease and peripheral artery disease), asthma, back pain, CKD stage 3-5, dyslipidaemia, gastro-oesophageal reflux disease, heart failure, hypertension, KOA, OSA, polycystic ovary syndrome, prediabetes, psoriasis, T2D and urinary incontinence.

Healthcare costs were the sum of costs for primary care, secondary care and prescriptions. Primary care included all appointments across primary care (GP consultations and practice nurse appointments). Secondary care included inpatient admissions (hospitalizations), outpatient care and emergency department visits. Prescriptions were grouped by British National Formulary chapter.[14] Prescriptions from the following chapters were excluded: 14 (Immunological Products and Vaccines), 15 (Anaesthesia), 18 (Preparations used in Diagnosis), 19 (Other Drugs and Preparations), 20 (Dressings), 21 (Appliances), 22 (Incontinence Appliances) and 23 (Stoma Appliances).

Primary care costs were derived from Personal Social Services Research Unit data from 2020.[15] Secondary care costs were derived from the Secondary Uses Service produced by NHS Digital. Prescription costs were calculated using net ingredient costs, obtained from the national report on the net ingredient cost of all prescriptions dispensed in England.[16] All costs are rounded to the nearest pound for presentation.

2.4 | Statistical analysis

All outcomes were age-standardized to the European Standard Population,[17] and costs were adjusted to 2019 costs using UK Consumer Price Index inflation data from the Office for National Statistics. Descriptive data are presented as means and standard deviations for continuous variables, and as numbers and percentages for categorical variables.

3 | RESULTS

3.1 | Study population and baseline characteristics

Overall, 1 410 146 individuals were included in the analysis (overweight: 1 008 101; obesity class I: 278 782; obesity class II: 80 621; obesity class III: 42 642). The proportion of women was greater in higher BMI groups (overweight: 45.9%; obesity class I: 50.6%; obesity class II: 60.5%; obesity class III: 65.3%) and mean age was similar across groups (40.7-43.1 years across groups; Table 1).

3.2 | Prevalence of obesity-related complications over 10 years

The prevalence of individual ORCs and ORC multimorbidity increased over time in all BMI groups, and was generally higher in successive BMI groups, particularly in the later years of follow-up; the only exceptions to this pattern were prediabetes and ASCVD (Figure 1; Table S2). The number of individuals in each year of follow-up is presented in Table S3.

The ORCs with the greatest prevalence at baseline were hypertension (20.6%-31.2% across groups) and T2D (7.5%-13.8%); those with the lowest prevalence were OSA (0.3%-1.9%) and heart failure (1.0%-2.3%; Figure 1; Table S2). At baseline, the proportion of individuals with one or more ORC was greater in higher BMI groups (overweight: 49.9%; obesity class I: 52.6%; obesity class II: 57.5%; obesity class III: 59.2%). The same pattern was observed for proportions with two or more ORCs (overweight: 23.7%; obesity class I: 25.9%; obesity class II: 30.0%; obesity class III: 32.2%) and three or more ORCs (overweight: 10.5%; obesity class I: 11.7%; obesity class II: 14.2%; obesity class III: 15.9%).

The prevalence of OSA, heart failure and atrial fibrillation was markedly higher in those with obesity class III compared with the other BMI groups, particularly towards the end of the 10-year follow-up period (Figure 1; Table S2). At year 10, 6.5% of individuals with obesity class III had OSA, compared with 1.0%-3.8% across the other BMI groups. Heart failure affected 3.6% of individuals with obesity class III at year 10, compared with 1.3%-2.5% across the other BMI groups. Atrial fibrillation affected 5.2% of individuals with obesity class III at year 10, compared with 2.6%-3.9%.

The prevalence of ORC multimorbidity increased substantially over the study period. By year 10, a greater proportion of individuals with obesity had one or more ORC (79.4%-84.2% across obesity classes) than those with overweight (73.2%; Figure 1; Table S2). More than 50% of individuals with obesity had two or more ORCs (53.0%-62.1%), compared with 44.5% with overweight, and more than 30% had three or more ORCs (31.8%-41.7%), compared with 24.9% with overweight.

3.3 | Changes in obesity-related complication prevalence over 10 years

Relative increases in the prevalence of individual ORCs and multimorbidity were generally greater for those with obesity relative to overweight, including for the three most common ORCs at baseline in the study population: hypertension, T2D and ASCVD (Figure 2). For hypertension, the relative increase in prevalence was 35.4% for

TABLE 1 Baseline characteristics by BMI group.

Baseline characteristic	Overweight (n = 1 008 101)	Obesity class I (n = 278 782)	Obesity class II (n = 80 621)	Obesity class III (n = 42 642)
Age, y, mean (SD)	41.2 (16.0)	43.1 (16.0)	42.8 (15.9)	40.7 (15.6)
Women, n (%)	462 678 (45.9)	141 035 (50.6)	48 805 (60.5)	27 836 (65.3)
BMI, kg/m^2, mean (SD)	26.9 (1.4)	31.9 (1.4)	37.0 (1.4)	46.4 (7.1)
Ethnicity, n (%)				
White	491 796 (48.8)	135 968 (48.8)	40 728 (50.5)	23 027 (54.0)
Asian or Asian British	281 849 (28.0)	69 206 (24.8)	16 715 (20.7)	7040 (16.5)
Black or Black British	87 480 (8.7)	31 693 (11.4)	10 812 (13.4)	5809 (13.6)
Mixed	28 744 (2.9)	8374 (3.0)	2625 (3.3)	1608 (3.8)
Other	88 074 (8.7)	24 149 (8.7)	6774 (8.4)	3573 (8.4)
Unknown	30 158 (3.0)	9392 (3.4)	2967 (3.7)	1585 (3.7)
Multimorbidity, age-standardized prevalence (%)				
≥ 1 ORC	49.9	52.6	57.5	59.2
≥ 2 ORCs	23.7	25.9	30.0	32.2
≥ 3 ORCs	10.5	11.7	14.2	15.9

Abbreviations: BMI, body mass index; ORC, obesity-related complication; SD, standard deviation.

individuals with overweight and 37.6%-39.7% across the obesity classes. For T2D, the prevalence increase was 69.3% for overweight and 97.9%-107.2% for obesity, and for ASCVD the prevalence increase was 19.5% for overweight and 24.1%-25.3% for obesity.

The ORCs with the largest relative increases in prevalence from baseline to year 10 were prediabetes (243.5%-417.6% across groups), CKD (163.2%-318.8%) and OSA (233.3%-280.0%; Figure 2). Increases in the prevalence of certain ORCs were greater for each successive BMI group. The stepwise relationship with BMI group was clearest for atrial fibrillation (overweight: 36.8%; obesity class I: 73.7%; obesity class II: 95.0%; obesity class III: 108.0%), but was also observed for KOA (overweight: 89.7%; obesity class I: 105.0%; obesity class II: 109.8%; obesity class III: 125.5%), T2D (overweight: 69.3%; obesity class I: 97.9%; obesity class II: 100.8%; obesity class III: 107.2%) and heart failure (overweight: 30.0%; obesity class I: 35.7%; obesity class II: 47.1%; obesity class III: 56.5%).

There was a greater increase in the prevalence of two or more ORCs, as well as of three or more ORCs among individuals with obesity, relative to overweight (Figure 2). The difference between overweight and obesity was greatest for three or more ORCs, and was smaller but still evident for two or more ORCs. For the prevalence of one or more ORC, increases were similar across BMI groups.

3.4 | Healthcare costs associated with multimorbidity

Higher BMI and the presence of a higher number of ORCs were both associated with comparatively higher annual per-person healthcare costs among individuals with multimorbidity (Figure 3). At year 1, costs in the groups with one or more ORC ranged from £935 (overweight) to £1214 (obesity class III), costs in the groups with two or more ORCs ranged from £1163 (overweight) to £1515 (obesity class III), and costs in the groups with three or more ORCs ranged from £1530 (overweight) to £1947 (obesity class III). Time at risk by year of follow-up is presented in Table S4.

Among individuals with obesity and multimorbidity, healthcare costs increased over time in individuals with one or more ORC, as well as in those with two or more ORCs, with greater increases in higher BMI groups (Figure 3). In those with one or more ORC, healthcare costs over 10 years increased by £75 for obesity class I, by £167 for obesity class II and by £305 for obesity class III. In those with two or more ORCs, healthcare costs increased by £39 for obesity class I, by £82 for obesity class II and by £230 for obesity class III. Healthcare costs remained comparatively stable over time in those with three or more ORCs.

Healthcare costs decreased over time in individuals with overweight and multimorbidity (Figure 3). Between year 1 and year 10, healthcare costs decreased by £74 in those with one or more ORC, by £103 in those with two or more ORCs and by £185 in those with three or more ORCs.

4 | DISCUSSION

This detailed analysis considered the prevalence of ORCs and multimorbidity, and associated healthcare costs in those with multimorbidity, in people living with overweight or obesity over 10 years, using real-world data from 2.7 million UK individuals.

Higher BMI was associated with increased baseline ORC prevalence and greater increases in ORC prevalence over time, and with higher healthcare costs in those with multimorbidity. The prevalence

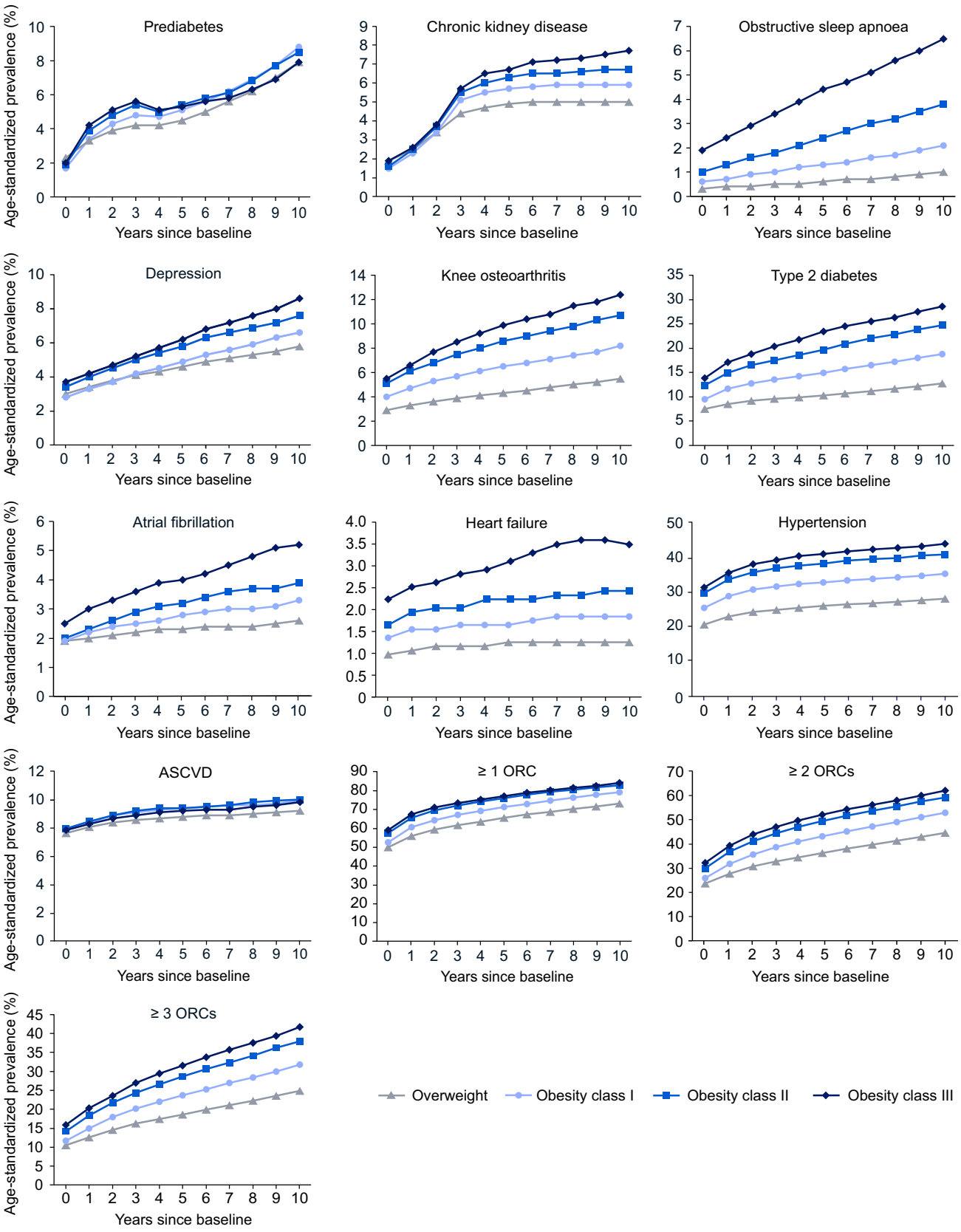

FIGURE 1 Prevalence of ORCs from baseline to year 10 in groups with overweight and obesity class I, II and III. Note that the y-axes differ between panels. ASCVD, atherosclerotic cardiovascular disease; ORC, obesity-related complication.

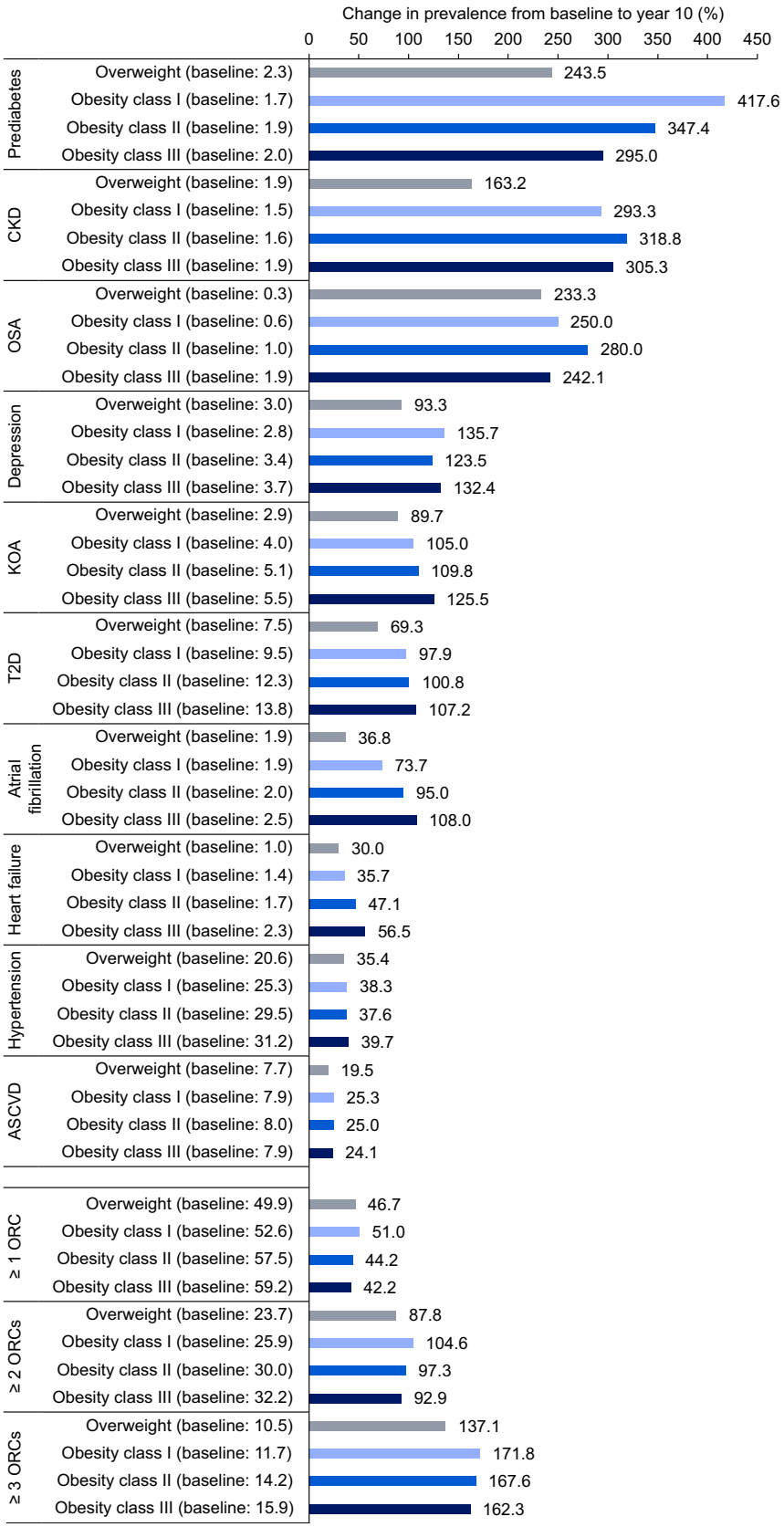

FIGURE 2 Changes in ORC prevalence from baseline to year 10 in groups with overweight and obesity class I, II and III. ASCVD, atherosclerotic cardiovascular disease; CKD, chronic kidney disease; KOA, knee osteoarthritis; ORC, obesity-related complication; OSA, obstructive sleep apnoea; T2D, type 2 diabetes.

of individual ORCs and the number of individuals with multimorbidity increased over a 10-year period, and was generally higher for each successive BMI group, with the greatest prevalence in obesity class III. OSA, heart failure and atrial fibrillation were markedly more prevalent in obesity class III than in the other obesity classes in each year of follow-up.

FIGURE 3 Healthcare costs associated with multimorbidity from baseline to year 10 in groups with overweight and obesity class I, II and III. Note that the y-axes differ between panels. GBP, pound sterling; ORC, obesity-related complication.

In general, there were greater increases over time in the prevalence of individual ORCs and multimorbidity in groups with obesity, relative to overweight, with a stepwise association between BMI group and increase in prevalence for KOA, T2D, atrial fibrillation and heart failure. Prediabetes, CKD and OSA were associated with the greatest increases in prevalence over follow-up, with more modest prevalence increases for ASCVD and hypertension, which were comparatively more common at baseline than the other ORCs in the analysis.

Throughout the 10-year follow-up period, both higher BMI and the presence of a higher number of ORCs were associated with greater healthcare costs in individuals with multimorbidity. Healthcare costs increased over time in those individuals with obesity and one or more ORC, and in those with obesity and two or more ORCs, with a greater rate of increase in each successive BMI group in these populations. Healthcare costs remained comparatively stable, at a high level, over time in individuals with obesity and three or more ORCs. By contrast, healthcare costs decreased over time in the overweight group.

These findings suggest that targeting prevention efforts at three key stages could reduce the burden of obesity on individuals and healthcare systems: first, preventing BMI progression via holistic weight-management programmes to reduce the risk of ORC development and greater healthcare costs; second, preventing ORC development by targeting ORCs with established increased risk such as CVD and musculoskeletal conditions; and finally, preventing acute complications in ORCs requiring hospitalization through effective risk management within obesity care pathways.

The increase in ORC prevalence over 10 years in our study is aligned with the findings of other analyses showing that multimorbidity has increased over recent decades, and is projected to continue increasing.[18,19] A previous analysis using the same Discover dataset identified similar trends in the proportion of individuals with diabetes living with co-morbidities and multimorbidity.[20] Additionally, the trend of greater increases in ORC prevalence among higher obesity classes has previously been observed in data from the United States.[21] New approaches to identifying, classifying and treating multimorbidity are required to manage this growing issue. In disease areas such as diabetes, concomitant conditions are already known to occur in non-random clusters, facilitating a holistic approach to management and treatment.[22,23]

The potential of emerging data science techniques and large real-world datasets should be harnessed to expand this approach, allowing multimorbidity to be predicted and its impact reduced or prevented by addressing modifiable risk factors.[22] For example, as the results of both the current study and previous analyses suggest, prevention or reversal of obesity progression to higher BMI groups is probable to reduce the risk of ORCs developing and progressing,[24,25] which in turn will avoid clinical events that would otherwise exacerbate morbidity and result in healthcare costs. Whereas co-existing conditions are currently assessed and treated in isolation by specialists, better integration within both research and clinical practice is required,[23] as recommended by existing NICE guidelines that advocate a tailored treatment approach for individuals with multimorbidity.[6]

A key strength of this analysis is the use of a previously published dataset[12,20] to provide granular insights into multiple ORCs and BMI groups, and how the corresponding unmet need varies over time. This is possible because of the large number of individuals in the Discover dataset, the long study duration and the richness of the available electronic health record data. The incorporation of all types of healthcare costs regardless of underlying causes permits holistic estimates of the impact of ORCs on patients and healthcare systems. Another strength was the use of a dynamic approach to ensure individuals who moved between BMI groups over the study period were categorized appropriately.

It should be noted that the Discover database is more diverse than the UK population in terms of ethnicity.[12] The likelihood of both obesity and certain co-morbidities varies between different ethnicities,[26,27] and, although we age-standardized to the European Standard Population, this may have had an impact on the findings of our analysis. Additionally, linked secondary care data were only available from 2015, which precluded the estimation of HCRU before this year. Future studies assessing ORCs and costs by BMI group in the

UK and other European countries will be valuable to gain further insights into trends over time. For example, a recent study assessed the impact of age, sex, deprivation and BMI group on HCRU and mortality in individuals with obesity in the UK.[28] Separately, future assessment of the costs of treating obesity will be of benefit to inform health economic analyses.

Electronic health records data and related research have the potential for misdiagnosis, miscoding and misclassification.[29] Our study compared outcomes between groups based on BMI and the number of ORCs, so assuming that the rates of these are similar between groups, the findings of the analysis are not expected to be significantly impacted. Finally, our analysis did not adjust for covariates; instead, results were externally age-standardized and descriptive epidemiology was used to provide insights for healthcare systems as to the unadjusted burden of illness.

Primary care-recorded BMI is incomplete in all electronic health records, including Discover.[30] This incompleteness is probably greater in groups with lower BMI because of less frequent interactions with the healthcare system, providing fewer opportunities for BMI measurement.[31] Therefore, compared with the obesity groups, a greater proportion of individuals in the overweight group may have had a BMI measurement as a result of seeking appointments to identify and manage cardiometabolic risks, including, for example, (pre)diabetes. The impact of subsequent management and broader lifestyle advice may have led to the overall slight reduction in healthcare costs observed in this group.

In conclusion, higher BMI is associated with increased baseline ORC prevalence and a greater increase in ORC prevalence over time. In individuals with multimorbidity, those with higher BMI had higher healthcare costs. Targeted efforts to prevent BMI progression and ORC development, and effective management of ORCs and prevention of their acute complications, would reduce the burden of ORCs on patients and healthcare systems. The presence, number and type of ORCs should therefore be an important consideration in holistic care pathways for people living with obesity.

AUTHOR CONTRIBUTIONS

SH and AT directly accessed and verified the underlying data reported in the manuscript. JP-S, SH and AT analysed the data. JP-S, SH, KSM, AT and SC had access to all data, and contributed to study concept and design. All authors contributed to drafting and critical revision of the manuscript text, and approved the manuscript for submission.

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CONFLICTS OF INTEREST STATEMENT

JP-S is Partner and Head of Health Analytics at Lane Clark & Peacock LLP, Chair of the Royal Society for Public Health, and reports personal fees from Novo Nordisk A/S and Pfizer Ltd outside of the submitted work. SH and AT are employees of Lane Clark & Peacock LLP; Lane Clark & Peacock LLP received consulting fees from Novo Nordisk A/S to perform this analysis. KSM and SC are employees of Novo Nordisk A/S.

DATA AVAILABILITY STATEMENT

The authors confirm that all data supporting the findings of this study are available within the article and its supplementary materials. Discover does not permit sharing or publication of individual patient data. Information on how to access Discover for research purposes can be found here: https://discover-now.co.uk/how-to-access-the-data/.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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