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# Factors associated with receiving an obesity diagnosis and obesity-related treatment for patients with obesity class II and III within a single integrated health system

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ABSTRACT

*Objectives:* The prevalence and associated adverse effects of obesity on health and healthcare cost make it a primary public health concern. However, individuals with the physiological features of obesity may be underdiagnosed and undertreated. We aimed to determine the prevalence of obesity diagnoses and obesity-related treatments in an integrated health system and determine the factors associated with receiving an obesity diagnosis and treatment for this indication.

*Methods:* This retrospective cross-sectional study of data from the Henry Ford Health electronic health record included adult patients with a body mass index (BMI) indicating clinical evidence of class II and III (severe) obesity in 2017 and who received treatment through 2019. The primary outcome was prevalence of obesity diagnosis and obesity-related treatment. Logistic regression evaluated the patient-level factors associated with odds of having obesity diagnosis and treatment.

*Results:* Among 64,741 patients meeting the clinical definition of definition of severe obesity, only 40.7 % were clinically diagnosed with obesity, and 23.5 % received an obesity-related intervention. Patients with BMI≥40 kg/m$^2$ (class III) were more likely to be diagnosed with obesity than those with BMI 35–39.9 kg/m$^2$ (class II) (odds ratio [OR] 5.84; 95 % CI, 5.62–6.07). Patients with a diagnosis of obesity (OR 2.92; 95 % CI, 2.80–3.05), Black patients (OR 1.46; 95 % CI, 1.40–1.53), and female patients (OR 1.47; 95 % CI, 1.41–1.54) were more likely to be offered obesity-related treatment.

*Conclusions:* Severe obesity may be underdiagnosed in patients who have BMI 35–39.9 kg/m$^2$ and 1 comorbidity.

## 1. Introduction

Obesity is a major public health concern in the United States (US) and throughout most of the world due to its high prevalence, direct and indirect adverse effects on health and quality of life, and cost to the healthcare system (Klein et al., 2002). Obesity was defined as a disease by the World Health Organization and Centers for Medicare and Medicaid Services in 2013 (World Health Organization, 2021), and by 2014, 66.2 % of women and 73.0 % of men worldwide met the clinical criteria for having overweight or obesity (National Center for Health Statistics, 2016). In 2016, 1.9 billion adults worldwide met the criteria for having obesity, accounting for 39 % of the global population (World Health Organization, 2021). Obesity is estimated to cost $173 billion a year within the US (Centers for Disease Control and Prevention, 2022), and multiple studies have suggested that obesity leads to frailty, poor health-related quality of life, and disease clustering (Agborsangaya et al., 2013; Fortin et al., 2004; Garin et al., 2016; Jackson et al., 2015; Kivimäki et al., 2017; Strandberg et al., 2012). It has also been linked to poorer mental health and serious comorbid conditions, including cardiovascular disease, diabetes, and cancer (Tucker et al., 2021). The

*Abbreviations:* BMI, body mass index; ICD-10CM, International Statistical Classification of Diseases and Related Health Problems, 10th revision, Clinical Modification; OR, odds ratio; US, United States; GLP-1, glucagon-like peptide 1.

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influence of obesity on some of these chronic conditions has been identified as one of the leading causes of death in the US and worldwide (D'Souza et al., 2018). Large observational studies have shown a three- to eight-year reduction in disease-free life in individuals with obesity (Nyberg et al., 2018), as well as a an up to three-fold increased risk of all-cause premature death (GBD 2015 Obesity Collaborators; Global BMI Mortality Collaboration, 2017). Importantly, individuals with obesity face damaging levels of societal stigma, which can have an additional impact on mental health and result in disparities in health care (Harwood et al., 2022; Lewis et al., 2016; Puhl and Heuer, 2010).

Primary care physicians encounter many patients with obesity, (Tucker et al., 2021) and the prevalence and associated disease burden are increasing worldwide (Dai et al., 2020; GBD 2019 Risk Factors Collaborators, 2020) to global epidemic proportions (Noria and Grantcharov, 2013). The clinical classification of obesity is important for medical evaluation and treatment, since being within a higher obesity class is associated with increased mortality (Berrington de Gonzalez et al., 2010; Flegal et al., 2013; Prospective Studies Collaboration, 2009). Weight and obesity categories defined in the World Health Organization recommendations are widely used and include a scale that goes from normal to overweight, obese, and severely obese with increasing body mass index (BMI) (Suissa et al., 2021; World Health Organization, 2000). Overweight and obesity are also specifically classified by the US Preventive Services Taskforce and Centers for Disease Control and Prevention as overweight, class I, II, and III obesity, also defined by increasing BMI ranges (Ackermann et al., 2008). Importantly, individuals with class II (BMI 35.0–39.9 kg/m$^2$) and class III obesity (BMI$\geq$40 kg/m$^2$) are at a higher risk of developing metabolic and cardiovascular disease and disability than those who are overweight or who have class I obesity (Dixon, 2010; Haslam and James, 2005; Walls et al., 2010). Also, evidence suggests that the prevalence of individuals approaching class III obesity is growing relative to those who are overweight or in class I (Walls et al., 2010; Sturm, 2007; Pasco et al., 2013). While obesity-related comorbidities are frequently addressed in primary care, obesity itself is chronically undertreated (Ciciurkaite et al., 2019; de Heer et al., 2019; Fitzpatrick and Stevens, 2017; Valero-Elizondo et al., 2019), and few studies have examined how obesity is diagnosed (Ciemins et al., 2020; Ciemins etal.,2021) or what clinical features are most important for the proper diagnosis of class II or III obesity in the US, especially in urban and medically underserved areas. A recent study within the US showed that documentation of an obesity diagnosis (BMI above 30) was associated with weight loss, even when controlling for confounding factors. (Ciemins et al.,2020).

Because obesity is associated with an increasing number of diverse disease burdens, it may be an important target for multimorbidity prevention that avoids the complexities of multitarget preventive regimens (Kivimäki et al., 2022). By undertreating obesity in the primary care setting, clinicians may be missing valuable opportunities to markedly improve the overall health of their patients at both the personal and population level (Tucker et al., 2021). Additionally, in the US, severe obesity is a hierarchical condition category code (HCC) required for risk adjustment; thus, HCC coding relies on International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) coding to assign risk scores to patients. Each HCC is mapped to an ICD-10-CM code, and severe obesity is scored high. Therefore, not adequately documenting the diagnosis and treatment of patients within the highest obesity range may be leaving millions of dollars in potential reimbursement unused, which could in turn be employed for providing meaningful interventions to this patient population.

The aim of this retrospective cross-sectional study was to assess the level at which patients with class II and class III obesity (herein collectively referred to as "severe obesity") were diagnosed with obesity and treated at our institution and to determine the parameters associated with both diagnosis and initiation of treatment specifically for obesity. Our goal was to determine to what level severe obesity may be underdiagnosed or undertreated at our institution so that policies and practices may be developed to better serve this patient population and prevent unnecessary future morbidity.

## 2. Materials and Methods

### 2.1. Study population

This was a cross-sectional retrospective study of patients who had the clinical parameters indicative of class II and III obesity and had two or more outpatient primary care encounters that took place between January 1, 2017, and January 31, 2017, within a large metropolitan health system in the US in the state of Michigan. Data were collected for the year 2017 to clearly delineate diagnostic and treatment trends from any that may have been affected by the COVID-19 pandemic that started in 2020. This study was approved by the Institutional Review Board at Henry Ford Health on March 24,2023 (IRB#16302). Due to the retrospective nature of the study, the need for consent was waived. This study aligned with all guidelines for the protection of human subjects.

### 2.2. Inclusion and exclusion criteria

Inclusion criteria included age 18–75 years, record of two or more clinical visits in 2017 in primary care clinics, and clinical evidence of class II or class III obesity. For the purposes of this study and to align with current recommendations of the Obesity Medicine Association, we use the term "severe obesity" instead of the now non-recommended term "morbid obesity." Based on Centers for Medicare and Medicaid Services criteria, we defined patients as having "severe obesity" if they had class II obesity defined as BMI 35.0–39.9 kg/m$^2$ with the presence of at least one comorbidity or class III obesity defined as BMI$\geq$40 kg/m$^2$ (Centers for Medicare and Medicaid Services, 2012). Diagnoses found on problem lists were not included. Comorbidities included the following per Medicare guidelines for surgical management of severe obesity (Centers for Medicare and Medicaid Services, 2019): type 2 diabetes, essential hypertension, hyperlipidemia/dyslipidemia, obstructive sleep apnea, obesity-hypoventilation syndrome, arthropathy of spine or weight-bearing joints, metabolic dysfunction–associated steatotic liver disease/steatohepatitis, and pseudotumor cerebri. Exclusion criteria included patients who had only one clinical visit during the study period. This criterion was used to assure that patients had a continuity of care and a primary care connection. (Fig. 1).

### 2.3. Dataset source and study variables

Data were obtained from the Henry Ford Health electronic health record databases and filtered based on inclusion/exclusion criteria. Comorbidities were defined as the presence of specific International Statistical Classification of Diseases and Related Health Problems, 10th revision, Clinical Modification (ICD-10-CM) codes corresponding to the aforementioned comorbidities. All possible ICD-10-CM codes were individually reviewed to assure correspondence with the comorbid diagnosis.

The following baseline patient characteristics were extracted: age, sex, race/ethnicity as reported in the medical record, BMI, median household income, obesity-related comorbidities, and number of obesity comorbidities. Age was also categorized as 18–35, 36–50, 51–64, and 65–75 years old. Sex was categorized as male and female. Race and ethnicity were categorized as self-reported in the medical record as Asian, Black/African American, Hispanic, White, and other/unknown. Median household income was obtained by mapping patients' addresses to census block group level median household income. Primary outcomes included the presence of a coded severe obesity diagnosis within the study period ("severe obesity diagnosis") and whether a medical intervention for severe obesity was ordered within the study period ("obesity-related intervention"), which includes both pharmacological therapy and referrals to specialists with the intent to directly treat severe

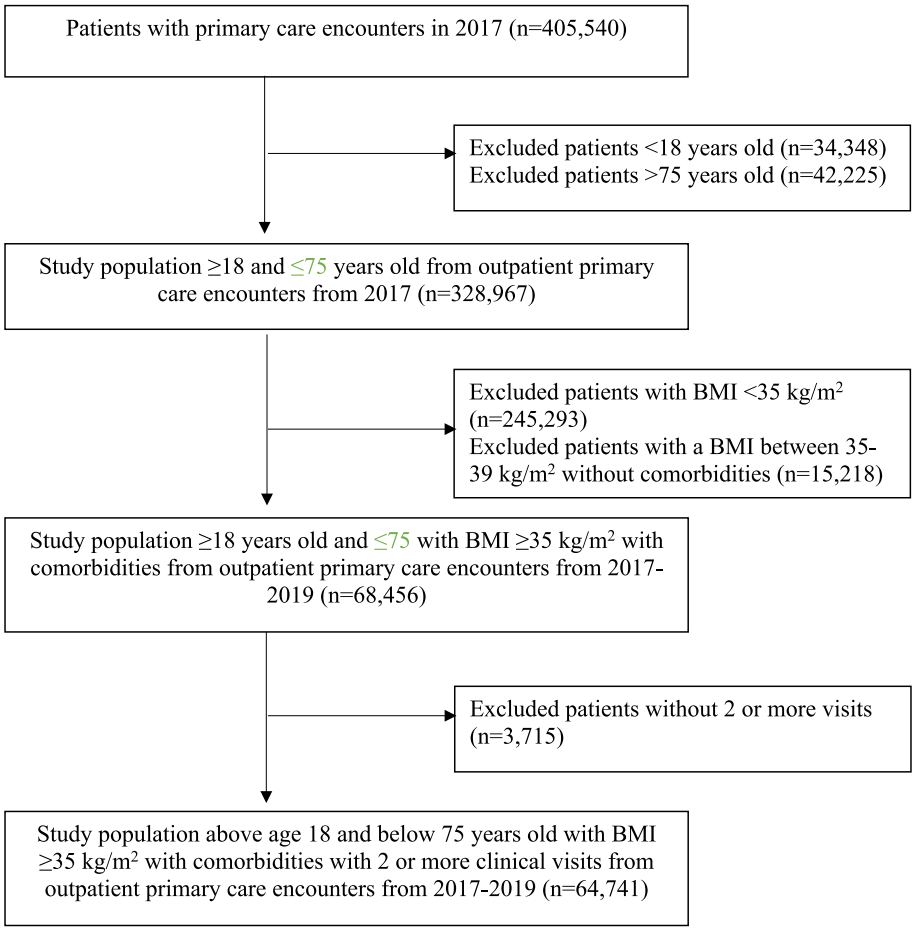


**Fig. 1.** Criteria to determine final study population in adult patients (2017–2019) within a large metropolitan health system in the US in the state of Michigan. Abbreviations: BMI, body mass index.

obesity. Patients were considered to have a severe obesity diagnosis if a corresponding ICD-10-CM code (E66.01 or E66.20) for "morbid obesity" was entered in the medical chart during the three-year study period. Likewise, patients were considered to have received a severe obesity-related intervention if a corresponding treatment was present in the chart within the same period. Anti-obesity medications included lorcaserin, phentermine, phentermine/topiramate, bupropion/naltrexone, orlistat, metformin, liraglutide, and semaglutide (brand name Ozempic-Wegovy was not approved for treating obesity during the study period). Of note, medications to treat diabetes that were given to patients who had a diabetes diagnosis were not considered as a severe obesity treatment in our model, as the treatment of diabetes with diabetes medication does not constitute a primary obesity treatment. However, medications indicated for treatment of diabetes that were prescribed for patients who did not have a diabetes diagnosis were presumed to be given with the intent to treat severe obesity and were included as an obesity-related intervention.

### *2.4. Data analysis*

Baseline characteristics were used as the main predictors in all models. Descriptive analysis included frequencies with percentages or means with standard deviations as applicable. Bivariate analysis of patient characteristics and outcomes to assess the patient characteristics associated with receiving a diagnosis of severe obesity or receiving obesity-related interventions was done with chi-square analysis. Logistic regression models assessed the association of the aforementioned variables with a diagnosis of severe obesity and with obesity-related intervention. Data were analyzed in SPSS version 26 (IBM, Armonk, NY).

## 3. Results

Of 405,540 medical records screened, a total of 64,741 patients (~16 %) had the clinical characteristics of severe obesity during the study period (63.2 % women and 36.8 % men). Of these patients, 37,733 (58.5 %) had BMI 35.0–39.1 kg/m$^2$ with at least one comorbidity and 27,008 (41.7 %) had BMI≥40 kg/m$^2$. The mean ± standard deviation age was 53 ± 13.6 years. Patients had a mean of 1.8 ± 1.2 obesity-related comorbidities, and most patients (72.5 %) had a median household income between $25,000 and $75,000 (Table 1). All demographic information and patient characteristics are summarized in Table 1.

The mean number of primary care visits within the study period for the entire cohort was 7.7 ± 6.2 visits, and most patients (42.1 %) had 5 to 9 visits. A total of 26,353 patients were clinically diagnosed with severe obesity during a clinical visit within the study period, revealing a 40.7 % prevalence of severe obesity diagnoses. There were 15,218 (23.5 %) patients who had an obesity-related intervention, and 8,744 (13.5 %) patients had a medication for treating obesity prescribed. A summary of healthcare and interventions for the study population is in Table 2.

Notably, of the 37,733 patients with physiological features of class II obesity, only 5,351 (19.8 %) were diagnosed with severe obesity and 4,298 (15.9 %) had an obesity-related intervention. Of the 27,008 patients with physiological features of class III obesity, 21,002 (55.7 %) were diagnosed with severe obesity, and 10,920 (28.9 %) had an obesity-related intervention (Table 3). Bivariate analyses showed that all variables were significantly associated with receiving a diagnosis of severe obesity or having an obesity-related intervention, including sex, age strata, race/ethnicity, obesity category, number of obesity-related

**Table 1**
Baseline demographic characteristics of adult patients 18–75 years old with clinical definition of class II or class III obesity in 2017 within a large metropolitan health system in the US in the state of Michigan.

| | Number (%) N=64,741 |
|---|---|
| **Sex** | |
| Female | 40,937 (63.2) |
| Male | 23,804 (36.8) |
| **Age, years, mean ± SD** | 53 ± 13.6 |
| **Age group in years** | |
| 18–35 | 8,340 (12.9) |
| 36–50 | 17,316 (26.7) |
| 51–64 | 24,586 (38.0) |
| 65–75 | 14,449 (22.4) |
| **Race and Ethnicity** | |
| Asian | 361 (0.6) |
| Black/African American | 20,536 (31.7) |
| Hispanic | 1,676 (2.5) |
| White | 38,875 (60.0) |
| Other/Unknown | 3,293 (5.1) |
| **Severe obesity category** | |
| Class II: BMI 35.0–39.9 kg/m$^2$ with obesity-related comorbidities | 37,733 (58.3) |
| Class III: BMI≥40 kg/m$^2$ | 27,008 (41.7) |
| **Obesity-related comorbidities** | |
| Hyperlipidemia | 28,234 (43.6) |
| Hypertension | 42,445 (65.6) |
| Nonalcoholic fatty liver disease | 1,184 (1.8) |
| Obesity-related hypoventilation | 293 (0.5) |
| Obstructive sleep apnea | 10,034 (15.5) |
| Osteoarthritis of weight-bearing joints | 11,090 (17.1) |
| Pseudotumor cerebri | 177 (0.3) |
| Type 2 diabetes | 22,342 (34.5) |
| **Number of obesity-related comorbidities, all, mean ± SD** | 1.8 ± 1.2 |
| **Number of obesity-related comorbidities** | |
| 0 | 10,380 (16.0) |
| 1 | 18,870 (29.1) |
| 2 | 16,447(25.4) |
| 3 | 13,249 (20.5) |
| 4 | 4,771 (7.4) |
| 5 | 943 (1.5) |
| 6 | 78 (0.1) |
| 7 | 3 (0.005) |
| **Median household income overall, US dollars, mean ± SD** | $58,202 ± $25,212 |
| **Median household income category, US dollars** | |
| <$25,000 | 3,744 (5.8) |
| $25,000 to <$50,000 | 21,372 (33.0) |
| $50,000 to <$75,000 | 25,604 (39.5) |
| $75,000 to <$100,000 | 9,220 (14.2) |
| ≥$100,000 | 4,039 (6.2) |
| Income data missing | 762 (1.2) |

BMI, body mass index; SD, standard deviation; US, United States.
*Data are reported as number (%) unless otherwise indicated.

comorbidities, median household income, and number of primary care visits (all $p < 0.001$) (Table 3).

Logistic regression analysis showed that individuals who had class III obesity were almost six times more likely to have received a diagnosis of severe obesity than those who had class II obesity (odds ratio [OR], 5.84; 95 % CI, 5.62–6.07). Other significant factors associated with having a diagnosis of severe obesity included Black/African American race (OR, 1.81; 95 % CI, 1.74–1.89) and number of comorbidities (OR, 1.37; 95 % CI, 1.35–1.39). Other factors such as female sex, age stratum, median household income, and number of primary encounters were significantly but modestly associated with a diagnosis of severe obesity (Table 4).

A second logistic regression analysis showed that patients who had been diagnosed with severe obesity during a primary care visit during the study period were almost three times more likely to receive an obesity-related intervention than those who did not (OR, 2.92; 95 % CI, 2.80–3.05). Black/African American (OR, 1.46; 95 % CI, 1.40–1.53) and female patients (OR, 1.47; 95 % CI, 1.41–1.54) were over 40 % more likely to be offered a medical intervention for obesity. All other demographic factors were significantly but modestly associated with having a medical intervention for obesity (Table 5). Of note, the number of comorbidities was negatively associated with having an obesity-related intervention (OR, 0.88; 95 % CI, 0.86–0.90).

**Table 2**
Follow-up characteristics of obesity diagnosis and obesity-related medical interventions in adult patients 18–75 years old (2017–2019) within a large metropolitan health system in the US in the state of Michigan.

| | Number (%)* N=64,741 |
|---|---|
| Number of primary care visits from 2017 to 2019, mean ± SD | 7.7 ± 6.2 |
| Number of primary care visits from 2017 to 2019 | |
| 2 to 4 | 21,725 (33.6) |
| 5 to 9 | 27,242 (42.1) |
| 10 or more | 15,774 (24.4) |
| Obesity diagnosed at visit | 26,353 (40.7) |
| Obesity-related intervention (all) | 15,218 (23.5) |
| Referral for obesity intervention | 8,429 (13.0) |
| Type of referral for obesity intervention | |
| Bariatric surgery | 2,522 (3.9) |
| Center for weight management | 2,150 (3.3) |
| Diabetes prevention program | 352 (0.2) |
| Nutrition services | 1,894 (2.9) |
| Preventive cardiology | 2,825 (4.4) |
| Preventive cardiology with weight management program | 2,825 (4.4) |
| Obesity medication prescribed† | 8,744 (13.5) |

SD, standard deviation.
* Data are reported as number (%) unless otherwise indicated.
† Includes diabetes medications for patients without diabetes diagnosis. Anti-obesity medications included lorcaserin, phentermine, phentermine-topiramate, bupropion, naltrexone, orlistat, metformin, liraglutide, and semaglutide.

## 4. Discussion

In this retrospective cross-sectional study of how patients were diagnosed with obesity and treated for obesity, over 50% of patients who had clinical characteristics indicative of obesity did not receive an obesity diagnosis during a medical visit within the study period. In our study, patients with class III obesity were much more likely to receive a diagnosis of severe obesity than individuals with class II obesity, suggesting that those with class II obesity may be particularly likely to be underdiagnosed. This finding is important, since we also saw that the presence of a severe obesity diagnosis was a key factor associated with whether or not a patient was offered an obesity-related medical intervention or treatment.

Extensive literature on severe obesity in relation to surgical procedures exists; however, limited studies have been done regarding the frequency or accuracy of diagnostic and treatment patterns for individuals with severe obesity (Centers for Medicare and Medicaid Services, 2019). To our knowledge, our study is one of only a few that have focused on the frequency and accuracy of receiving a diagnosis of and treatment for obesity per the HCC code. Previous studies have shown that the sensitivity of diagnostic coding for obesity is low, and coding errors might be a factor influencing results of studies that implemented code-based obesity diagnosis. However, whether diagnosis of severe obesity is prone to similar coding inaccuracies is not clear (George et al., 2017; Golinvaux et al., 2014).

In our population, Black patients and female patients were more likely to receive an obesity-specific treatment. However, we note that the OR describing the association of female sex with treatment was 1.04, and this finding may not be clinically relevant. But Black patients were almost twice as likely to receive an obesity-specific treatment in our study. Obesity disparities are known to exist for Black and Latino adults, and clinical trials for weight loss drugs often do not recruit representative populations (Herbozo et al., 2023). However, a study looking at

**Table 3**
Bivariate analysis of the association between patient characteristics and receiving a diagnosis of severe obesity diagnosis or an obesity-related intervention in adult patients 18–75 years old with severe obesity within a large metropolitan health system in the US in the state of Michigan (2017–2019).

| | All Patients with Severe Obesity N=64,741 No. | Severe Obesity Diagnosis n = 26,353 No. and row % | P value | Obesity-Related Intervention n = 15,218 No. and row % | P value |
|---|---|---|---|---|---|
| **Sex** | | | <0.001 | | <0.001 |
| Female | 40,937 | 17,417 (42.5) | | 11,019 (26.9) | |
| Male | 23,804 | 8,936 (37.5) | | 4,199 (17.6) | |
| **Age group, years** | | | <0.001 | | <0.001 |
| 18–35 | 8,340 | 3,761 (45.1) | | 2,729 (32.7) | |
| 35–50 | 17,316 | 7,630 (44.1) | | 5,327 (30.8) | |
| 51–64 | 24,586 | 9,586 (39.0) | | 5,347 (21.7) | |
| 65–75 | 14,449 | 5,376 (37.1) | | 1,815 (12.5) | |
| **Race and Ethnicity** | | | <0.001 | | <0.001 |
| Asian | 361 | 119 (32.9) | | 109 (30.2) | |
| Black/African American | 20,536 | 10,107 (49.2) | | 6,059 (29.5) | |
| Hispanic | 1,676 | 680 (40.6) | | 486 (29.0) | |
| White | 38,875 | 14,098 (36.3) | | 7,785 (20.0) | |
| Other/Unknown | 3,293 | 1,349 (41.0) | | 779 (23.7) | |
| **Severe obesity category** | | | <0.001 | | <0.001 |
| Class II: BMI 35–39.9 kg/m$^2$ with obesity-related comorbidities | 37,733 | 5,351 (19.8) | | 4,298 (15.9) | |
| Class III: BMI≥40 kg/m$^2$ | 27,008 | 21,002 (55.7) | | 10,920 (28.9) | |
| **Number of obesity-related comorbidities** | | | <0.001 | | <0.001 |
| 0 | 10,380 | 4,498 (43.3) | | 3,263 (31.4) | |
| 1 | 18,870 | 6,283 (33.3) | | 4,731 (25.1) | |
| 2 | 16,447 | 6,425 (39.1) | | 3,827 (23.3) | |
| 3 | 13,249 | 5,739 (21.8) | | 2,273 (17.2) | |
| 4 | 4,771 | 2,866 (56.3) | | 891 (18.7) | |
| 5 | 943 | 658 (69.8) | | 210 (22.3) | |
| 6 | 78 | 61 (78.2) | | 21 (26.9) | |
| 7 | 3 | 3 (100) | | 2 (66.7) | |
| **Median household income category (US dollars)** | | | <0.001 | | <0.001 |
| <$25,000 | 3,744 | 1,704 (45.5) | | 987 (26.5) | |
| $25,000 to <$50,000 | 21,372 | 9,512 (44.5) | | 5,354 (25.1) | |
| $50,000 to <$75,000 | 25,604 | 9,752 (38.1) | | 5,798 (22.6) | |
| $75,000 to <$100,000 | 9,220 | 3,509 (38.1) | | 2,100 (22.8) | |
| ≥$100,000 | 4,039 | 1,557 (38.5) | | 947 (23.4) | |
| **Number of primary care visits 2017–2019** | | | <0.001 | | <0.001 |
| 2 to 4 | 21,725 | 7,643 (35.2) | | 4,217 (19.4) | |
| 5 to 9 | 27,242 | 11,689 (42.9) | | 6,825 (25.1) | |
| 10 or more | 15,774 | 7,021 (44.5) | | 4,176 (26.6) | |

BMI, body mass index; US, United States.
*Study groups are described as number and row % with the All Patient row data as denominator.
Statistical significance $p < 0.05$ based on chi-square analysis.

**Table 4**
Adjusted multivariable logistic regression analysis of characteristics associated with diagnosis of severe obesity in adult patients 18–75 years old (2017–2019) within a large metropolitan health system in the US in the state of Michigan.

| Covariate | Odds Ratio (95 % CI) | P value |
|---|---|---|
| Class III obesity (Ref: Class II) | 5.84 (5.62–6.07) | <0.001 |
| Female sex (Ref: Male) | 1.04 (1.00–1.08) | <0.05 |
| Age stratum (Ref: 18–35 years) | 0.87 (0.86–0.89) | <0.001 |
| Black/African American race (Ref: White) | 1.81 (1.74–1.89) | <0.001 |
| Number of obesity-related comorbidities | 1.37 (1.35–1.38) | <0.001 |
| Median household income stratum (Ref: <$25,000) | 1.06 (1.04–1.08) | <0.001 |
| Number of primary care encounters stratum (Ref: 2–4 visits) | 1.21 (1.18–1.24) | <0.001 |

BMI, body mass index; Ref, reference; Class III Obesity, BMI≥40 kg/m$^2$; Class II Obesity, BMI 35–39.9 kg/m$^2$ with obesity-related comorbidities; Age Strata (13–35, 35–50, 51–64, ≥65 years); Median household income strata in US$ (<$25,000; $25,000 to <$50,000; $50,000 to <$75,000; $75,000 to <$100,000; ≥$100,000); Number of primary care encounters (2–4; 5–9; 10 or more).
Relative to individuals with BMI 30–39.9 kg/m$^2$ and one comorbidity.
Odds ratios (OR) and 95 % confidence intervals derived from logistic regression. Fully adjusted models included obesity class, sex, age, race, number of comorbidities, median household income, and number of primary care encounters. Statistical significance $p \leq 0.05$.

anti-obesity medication use trends from 2010 to 2019 also showed that African American patients were more likely to receive anti-obesity pharmacotherapy, and the authors suggest that health care provider practice may be a major cause (Elangovan et al., 2021). Considering the growing popularity of newly approved GLP-1 anti-obesity drugs, understanding how both patient and provider knowledge and beliefs play a role in prescribing behaviors will be important.

### 4.1. Limitations

Multiple limitations are inherent to large-scale studies using retrospective data from patient databases. The use of ICD-10-CM codes in lieu of actual diagnoses may underestimate rates of diagnosis. Likewise, orders such as treatments and referrals often require association with an ICD-coded diagnosis, which could partially explain why diagnosis of obesity was such a strong potential predictor of treatment. However, the lack of such diagnoses also suggests a lack of treatment for severe obesity, highlighting the importance of a diagnosis. Interventions such

**Table 5**
Adjusted multivariable logistic regression analysis of characteristics associated with receiving a severe obesity intervention strategy in adult patients 18–75 years old (2017–2019) within a large metropolitan health system in the US in the state of Michigan.

| Covariate | Odds Ratio (95 % CI) | P value |
|---|---|---|
| Obesity diagnosis at a visit (Ref: No) | 2.92 (2.80–3.05) | <0.001 |
| Class III obesity (Ref: Class II) | 1.17 (1.12–1.22) | <0.001 |
| Female sex (Ref: Male) | 1.47 (1.41–1.54) | <0.001 |
| Age stratum (Ref: 18–35 years) | 0.72 (0.71–0.74) | <0.001 |
| Black/African American race/ethnicity | 1.46 (1.40–1.53) | <0.001 |
| Number of obesity-related comorbidities | 0.88 (0.86–0.90) | <0.001 |
| Median household income stratum (Ref: <$25,000) | 1.10 (1.08–1.12) | <0.001 |
| Number of primary care encounters stratum (Ref: 2–4 visits) | 1.37 (1.33–1.41) | <0.001 |

BMI, body mass index; Ref, reference; Class III Obesity, BMI≥40 kg/m$^2$; Class II Obesity, BMI 35–39.9 kg/m$^2$ with obesity-related comorbidities; Age Strata (13–35; 35–50; 51–64; ≥65 years); Median household income strata in US$ (<$25,000; $25,000 to <$50,000; $50,000 to <$75,000; $75,000 to <$100,000; ≥$100,000); Number of primary care encounters (2–4; 5–9; 10 or more).
Relative to individuals with BMI 30–39.9 kg/m$^2$ and one comorbidity.
Odds ratios (OR) and 95 % confidence intervals derived from logistic regression. Fully adjusted models included obesity diagnosis at visit, obesity class, sex, age, race, number of comorbidities, median household income, and number of primary care encounters. Statistical significance $p \leq 0.05$.
Ms. No.: PMEDR-24–436.

as motivational interviewing, which may only be captured by visit diagnoses such as exercise counseling or dietary counseling, were also not captured. Other variables that may be associated with obesity diagnosis and treatment could not be obtained from our database, which may have influenced our results. These include but are not limited to provider specialty, provider level of training, and patients' preferred language. While considering these factors may or may not have altered our results, they may be important to include in future studies to provide insight into the specific types of providers and patients who may disproportionately benefit from education or a focused intervention. Also, contraindications for treatment were not considered in our models, which may have led to an underestimation of the treatments that were provided. For medications, these would include absolute and relative contraindications to treatment, such as use of other medications or presence of other diseases. For referrals, these would include absolute and relative contraindications for surgery, intensive diet, or intensive exercise regimen. This would have produced innumerable potential parameters to be considered in the models, many of which were unavailable in the database or may have been subject to a provider's interpretation of the clinical context. As such, these were not included in the final models.

Finally, in our study and in the literature at large, analyzing treatment of severe obesity with pharmaceutical interventions for patients with diabetes presents a logistical challenge. Medical treatments for severe obesity in our study were largely divided into two categories: obesity-specific medications and diabetes medications that promote weight loss and may be prescribed for patients without diabetes. By removing treatment with a diabetes medication for patients with diabetes as a variable, we may have underestimated the number of pharmaceutical interventions that were intended to treat obesity. For example, treating patients who have diabetes with metformin, a first-line diabetes medication, could also be considered as intent to treat severe obesity. Although inclusion of this treatment and group was considered, we felt that it might markedly overestimate the rate of treatment for severe obesity. While we could have removed all patients with diabetes from the analysis, we felt that this would have removed a large segment of the study population, as diabetes is not only highly prevalent in patients with clinical characteristics of obesity, but also is one of the risk factors in the definition of class II obesity. Importantly, patients included in our study had been treated before the most popular of the latest GLP-1 drugs had been approved for weight loss, and these drugs now represent a paradigm shift in the medical approach to treating obesity and diabetes. Thus, prospective studies on rates of obesity diagnosis and treatment in this new GLP-1 era are needed to determine how these rates may change.

Lastly, the translation of electronic medical record data into meaningful clinical definitions relies heavily on the clinical team's perspectives on common clinical practices. Therefore, bias is inherent when using visit diagnoses and orders as variables and outcomes.

## 5. Conclusions

Our findings suggest that a potentially high-yield intervention for treating patients with severe obesity would be to increase the rate of severe obesity diagnoses, especially for individuals with class II obesity. This might be achieved through policies that emphasize screening for severe obesity within this population, as the diagnosis requires the presence of at least one comorbidity, and therefore extends it beyond a 1-step, simple definition. Within the context of the electronic medical record, an electronic prompt suggesting an obesity diagnosis and potential treatments might encourage clinicians to address the possibility of diagnosing severe obesity more frequently. System-wide registries similar to those used for diabetes, tobacco use, and hypertension would allow changes to be instituted at the system level. Finally, patient-driven efforts towards treatment may increase if patients are educated about the criteria for diagnosis, associated morbidity and mortality, and potential treatment options.

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## CRediT authorship contribution statement

**Raphael Szymanski:** Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Megha Abraham:** Writing – original draft, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **William Childs:** Writing – original draft, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Kristina Le:** Writing – original draft, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Christopher Velez:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ivana Vaughn:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Lois Lamerato:** Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Katarzyna Budzynska:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The data that has been used is confidential.

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