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Prevalence and Recognition of Obesity and its Associated Comorbidities in a Large U.S. Integrated Health System

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Keywords: Obesity, Diagnosis, Comorbidities, Body Mass Index, Integrated Delivery System, Electronic Health Records

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ABSTRACT

Objective: To determine the prevalence of obesity and its related comorbidities among patients being actively managed at a U.S. academic medical center, and to examine the frequency of a formal diagnosis of obesity, via ICD-9 documentation among patients with BMI $\geq$30 kg/m^2.

Design: The electronic health record system at Cleveland Clinic was used to create a cross-sectional summary of actively-managed patients, stratified by BMI categories, as of July 1, 2015. Relationships between patient characteristics and BMI categories were tested.

Setting: A large U.S. integrated health system

Results: A total of 324,199 active patients with a recorded BMI were identified. There were 121,287 (37.4%) patients found to have overweight (BMI ≥25 and < 29.9), 75,199 (23.2%) had BMI 30-34.9, 34,152 (10.5%) had BMI 35-39.9 and 25,137 (7.8%) had BMI ≥40. There was a higher prevalence of T2D, prediabetes, hypertension and cardiovascular disease (P-value <0.0001) within higher BMI compared to lower BMI categories. In patients with a BMI > 30 (N = 134,488), only 48% (64,056) had documentation of an obesity ICD-9 code. In those patients with a BMI > 40, only 75% had an obesity ICD-9 code.

Conclusions: This cross-sectional summary from a large U.S. integrated health system, found that 3 out of every 4 patients had overweight or obesity based on BMI. Patients within higher BMI categories had a higher prevalence of comorbidities. Less than half of patients who were identified as having obesity according to BMI received a formal diagnosis via ICD-9 documentation. The disease of obesity is very prevalent yet underdiagnosed in our clinics. The under diagnosing of obesity may serve as an important barrier to treatment initiation.

Article Summary

Strengths and Limitations of this study:

- The analysis included a very large sample of 324,199 patients with recorded BMI values.
- The electronic health records (EHR) used for the study (Cleveland Clinic) provide a rich source of demographic, clinical, laboratory, and prescription data on patients.
- Overweight and obesity categorizations were based on actual BMI calculations, not ICD coding.
- As a potential limitation, all patients were identified from a single institution's EHR, albeit one of the largest in the world (Cleveland Clinic).
- Another limitation is that all subjects were individuals seeking healthcare services, thus possibly not representative of the broader U.S. population.

Introduction

Obesity represents a major public health problem in the United States from the dual aspects of prevalence and consequence. The prevalence of obesity in the United States has nearly tripled over past decades, increasing from 13% in 1960–1962 to 36.5% during 2011–2014,[1] thus affecting an estimated 60 million American adults. Obesity is associated with a number of important chronic diseases such as type 2 diabetes (T2D), hypertension (HTN), dyslipidemia, coronary heart disease, stroke, several cancers, disability, and increased mortality.[2-7]

The U.S. Preventive Services Task Force (USPSTF) recommends screening all adults for obesity,[8] recognizing that health care providers have an important role in preventing, identifying and managing this chronic disease. The USPSTF also recommends that once a diagnosis of obesity has been established, physicians should offer or refer patients with a body mass index (BMI) ≥30 kg/m^2 to an intensive, interdisciplinary lifestyle intervention program.[8]

Despite these recommendations and formal recognition by the American Medical Association as a disease,[9] obesity continues to be underdiagnosed in clinical practicel.[10] It is estimated that less than 30% of obese adults receive this diagnosis during their primary care physician (PCP) visit.[10] Furthermore, discouraging data suggest that weight counseling as a component of primary healthcare services in the US has been declining significantly over the past decade.[11,12] Yet, the literature[13] is clear that obesity screening and recognition of the diagnosis are among the first steps leading to effective treatment. Obesity-related electronic health records have been highlighted as a useful tool to assist health care providers in the screening and management of obesity.[14-17]

The primary objective of the present study was to determine the true prevalence of obesity and related comorbidities among patients being actively managed at the Cleveland Clinic using EHR data. A secondary goal was to evaluate how frequently a formal diagnosis of obesity, via ICD-9 coding, was documented among patients with a BMI ≥ 30 kg/m^2.

Methods

The enterprise-wide electronic health record (EHR) system at Cleveland Clinic was used to create a cross-sectional summary of actively-managed patients, stratified by BMI categories, as of July 1, 2015. All Cleveland Clinic facilities utilize the MyPractice EHR system, composed of an integrated suite of software modules created by Epic® Systems (Verona, WI), and which was first installed in 1998. The

EHR includes patient demographics, social, medical, family and surgical history, vital signs, imaging data and pathology reports, and rich longitudinal clinical data (diagnosis, procedures, etc.) from both the inpatient and outpatient records. It contains discrete data linkage with Cleveland Clinic laboratory records, as well as detailed medication usage information. In 2014, Cleveland Clinic set a new annual record for outpatient visits (almost 6 million), and has >1 million active patients (2 or more encounters within the past 12 months).

Patients were identified by calculating the BMI from the most recent weight and median of all recorded heights obtained on or before the index date (July 1, 2015). The weight recorded closest to the index date was recorded as the study weight. Height and weight measures were obtained from outpatient encounters excluding ophthalmology, orthopedic, and psychiatry specialty visits because of a lack of precision of height and weight measurements obtained at these encounters. Patients were included if they were ≥20 years of age on the index date (as they may not have reached their full height by 18 years of age). Patients were only included in the analysis if they were seen by a PCP at least 3 times prior to the index date, and at least one of the visits must have occurred within the immediate 18 months preceding the index date.

Patients were excluded for any of the following reasons: median height <4'6" or >7'6"; weight >750 lbs (340 kg); pregnant or having recently given birth; amputees; diagnosis of HIV prior to the index date; diagnosis of hyperthyroidism, hypothyroidism, heart failure, radiation or chemotherapy treatment, or metastatic cancer between July 1st, 2013 and the index date (July 1st, 2015).

Income was defined as the five-year estimates (2008-2012) of median household income at the block group level obtained from the American Community Survey conducted by the U.S. Census Bureau.[18] The census block group was obtained by geocoding the patient address that was on file closest to baseline. BMI, weight, and smoking status were defined as the value recorded in the EHR closest to baseline (but without any time restrictions). Demographic and laboratory/vital sign data were recorded based on the most recent values available in the EHR on or before the index date. Comorbidities were identified in the EHR anytime up until the index date.

Relationships between patient characteristics and weight classifications (BMI categories) were tested using univariate analysis, where chi-square was used for testing the association between the weight classifications and a categorical characteristic. The non-parametric Kruskal-Wallis test was used for continuous characteristics.

This study was approved by the Cleveland Clinic's Institutional Review Board.

Results

As of July 1st, 2015, a total of 324,199 active patients with a recorded BMI were identified to meet the inclusion/exclusion criteria. Of these, 255,775 (78.9%) patients met criteria for overweight or obesity according to their recorded BMI: 121,287 (37.4%) were found to be overweight, 75,199 (23.2%) had obesity class I (BMI 30-34.9), 34,152 (10.5%) had obesity class II (BMI 35-39.9) and 25,137 (7.8%) had obesity class III (BMI ≥40). The median time from July 1st, 2015 until the closest measurement of BMI was 4.7 months (interquartile range [IQR]: 1.9 to 13.2 months) for all 324,199 patients. The median time from July 1st, 2015 until the closest measurement of BMI for those with a BMI ≥ 25 (n = 255,775) and for BMI < 25 (68,424), was 4.4 months (IQR: 1.8, 9.4) and 6 months (IQR: 2.3, 11.9), respectively.

All measured associations between the weight classifications and the patient characteristics were statistically significant (P<0.0001).

Study Population

Table 1 provides study population characteristics and demographics. The median (IQR) age for the entire cohort was 52 years (40, 63) and the slight majority of patients were female (54%). The population included Caucasians (77.4%), African-Americans (12.9%), Hispanics (3.6%) and Asian/Pacific Islanders (1.4%).

Based on height and weight measurements, 78.9% of the patients had BMI values classified as overweight or obesity. For obesity class I (BMI 30-34.9), a higher percentage were males (53%), unlike patients with BMI <25 (30%) or obesity class II and III (44% and 35%, respectively). There was a significantly smaller percentage of males than females within the obesity class III category (35% vs. 65%, respectively).

The proportion of African-American individuals with overweight or obesity increased across all BMI groups, while this pattern was not observed across all BMI cohorts for other races.

The prevalence of smoking was similar among the various BMI categories compared to individuals with normal BMI.

As BMI category increased, median household income decreased. The median household income (in US $) stratified by BMI category was: $62,210 (BMI <25); $62,500 (BMI 25-29.9); $58,300 (BMI 30-34.9); $53,890 (BMI 35-39.9); and $49,940 (BMI ≥40).

Documentation of an ICD-9 Code for Obesity. Out of 134,488 patients with a BMI ≥30, 48% (n=64,056) had a documented ICD-9 code for a diagnosis of obesity (ICD-9: 278.0x, V85.3x, V85.4x). Among patients with a BMI ≥40 (n=25,137), 75% (n=18,937) had an ICD-9 code for a diagnosis of obesity. In all 3 obesity classes, only a minority had a V85.x code for obesity class.

Comorbidities

Table 2 presents data on comorbidity patterns in the study population, stratified by BMI category. The proportion of patients with diabetes or pre-diabetes rose with increasing BMI category. The prevalence of T2D and prediabetes, stratified by BMI categories were as follows: BMI < 25: 4.5%, 0.9%; BMI 25-29.9: 12.5%, 10.6%; BMI 30-34.9: 19.3%, 13.7%; BMI 35-39.9: 25.7%, 14.9% and BMI ≥ 40: 30.9%, 16.9% respectively.

The proportion of patients with HTN was also observed to rise with increasing BMI category. The prevalence of HTN, stratified by BMI categories, was as follows: 23.2% (BMI < 25); 40.8% (BMI 25-29.9); 51.3% (BMI 30-34.9); 56.9% (BMI 35-39.9); and 61.9% (BMI ≥ 40). Both median systolic and diastolic blood pressures (BP, mmHg) were noted to rise with increasing BMI category.

There was no clinically meaningful difference in the median levels of LDL cholesterol (mg/dL) among the different BMI categories. Median HDL cholesterol levels were observed to decline with increasing BMI category: 65 mg/dL (BMI <25); 53 mg/dL (BMI 25-29.9); 48 mg/dL (BMI 30-34.9); 46 mg/dL (BMI 35-39.9); 45 mg/dL (BMI ≥ 40). Median triglyceride levels were as follows: 74 mg/dL (BMI <25); 97 mg/dL (BMI 25-29.9); 114 mg/dL (BMI 30-34.9); 119 mg/dL (BMI 35-39.9); and 117 mg/dL (BMI ≥40).

Patients with BMI ≥25 had a slightly higher prevalence of coronary artery disease compared to individuals with BMI <25, but no clinically meaningful differences in the prevalence of heart failure were observed between the BMI categories. There were no significant differences in the prevalence of cerebrovascular disease or glomerular filtration rate [calculated via CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration)] among the different groups of patients with obesity compared to lean subjects.

Glycemic control. The median fasting blood glucose values in overweight and obese individuals were higher compared with patients with BMI <25 (**Table 2**). Median HbA1c values and random blood glucose measures for patients with overweight and obesity were marginally higher than in patients with BMI <25.

Medications. As shown in **Table 3**, HTN medication utilization rose with increasing BMI categories: 19.5% (BMI <25); 35.5% (BMI 25-29.9); 44.9% (BMI 30-34.9): 50.4% (BMI 35-39.9); and 54.3% (BMI ≥ 40). Also, 30.8% of patients with obesity (BMI >30) were using a medication to control their cholesterol, whereas only 12.1% of lean subjects (BMI <25) were taking lipid-lowering medications (all P<0.0001). Patients with obesity were also more likely to be using a second lipid-lowering medication in addition to a statin.

Discussion

The results of this study showed that 37.4% of patients recently being cared for at the Cleveland Clinic were classified as overweight according to BMI, whereas 41.5% of patients had a BMI that categorized them as obese. Thus, only about one in five patients had a BMI that was not indicative of overweight or obesity. The prevalence of overweight/obesity in this population (78%) is somewhat higher than estimated recently for the general US population; just over two-thirds (69%) of adults were estimated to be overweight or obese in the US between 2009-2012.[19,20] This observation could be, in part, because the population seeking medical care at our institution may be sicker, whereas the number reported through National Center for Health Statistics is self-reported/survey based.

Data from the National Health and Nutrition Examination Survey[1] demonstrated that the prevalence of obesity was 36.5% among U.S. adults during 2011–2014. The prevalence of obesity was noted to be higher in women and among non-Hispanic black and Hispanics. Consistent with these data, we identified a higher percentage of females compared with males among obesity classes II and III in our patient population. Higher rates of obesity diagnosis in female patients have been theoretically attributed to more frequent healthcare utilization by women in general or sex bias on the part of providers.[21] However, the current study was based on objective BMI data, thus sex bias was clearly not a factor. While the percentage of female patients was slightly higher than that of male patients in the overall study population, the ratio of female to male subjects in the highest BMI categories was greater. We also identified a higher prevalence of African-Americans and a lower median household income within the higher BMI categories, compared to non-overweight/obese individuals.

Diabetes is another global health epidemic that is driven largely by rising obesity rates.[22] Excess body fat increases the risk for prediabetes; obese men and women, respectively, have a 7-fold and 12-fold higher risk for developing T2D.[23] In the current dataset, 15% of the entire study population had a diagnosis of T2D. This finding corroborates those of a recent report which estimated the prevalence of diabetes among U.S. adults in 2011-2102 to be 12-14%.[24] However, the prevalence of pre-diabetes in the current study population (10%) was markedly lower than reported previously (38%).[24] The Cleveland Clinic employs strict criteria for a diagnosis of pre-diabetes, which may partly explain the discrepancy. We also noticed that patients with higher BMI had higher prevalences of T2D and prediabetes compared to leaner subjects.

Patients with obesity and T2D often have an increased incidence of cardiovascular disease risk factors, such as hypertension and dyslipidemia,[25,26] which is not surprising given that both obesity and T2D are independent risk factors for cardiovascular disease.[25,27] In agreement with these observations, our study found higher prevalences of hypertension and dyslipidemia (per cholesterol-lowering medication utilization) among patients with obesity compared to leaner subjects. We also noted an increased prevalence of coronary artery disease and congestive heart failure in our patients with obesity compared to lean subjects.

The U.S. Preventive Task Force (USPSTF) recommends screening all adults for obesity[8], yet the U.S. healthcare system still faces challenges in this area. The continued lack of recognition of obesity as a disease and under-diagnosis by clinicians postpones the initiation of treatment and increases the risk of developing complications. Body weight is a modifiable risk factor, and weight loss of 5-10% has been shown to improve multiple health outcomes, including cardiovascular risk factors.[28] In obese patients with T2D, benefits of weight loss may include improvements in insulin sensitivity, sleep apnea, less depression, less urinary incontinence, reduced need of diabetes medications, improved quality of life, and even lower costs[28,29]. Significant weight loss has even been associated with remission of T2D.[30] Several reasons have been suggested as responsible for why providers are reluctant to include obesity in the list of diagnoses in patients with BMI >30. These include: perception by health care providers that obesity is not a disease, low expectations for patient success, lack of time or knowledge to provide appropriate advice regarding nutrition, societal stigma, concerns with denials of payment for services, and limited therapeutic tools to treat patients with obesity.[12,15,31,32]

Identifying obesity is the first step leading to optimal interdisciplinary intervention ideally involving lifestyle modifications relating to nutrition and physical activity, as well as medications where necessary

to reduce appetite. Optimal obesity-related EHR functions should help to carry out this important task. We took advantage of our institution's EHR functions to document what is probably the most relevant finding of our study. In addition to identifying BMI-defined obesity in more than 40% of our patients, we observed that only half of such patients received a formal diagnosis of obesity via ICD-9 coding (278.00). Several studies have demonstrated the usefulness of EHR functions for screening and treating obesity, specifically with regard to assessing BMI, diagnosing obesity, and facilitating obesity counseling and treatment services.[16,17,33] In compliance with meaningful use standards, EHRs are required to calculate BMI for all patients, as well as plot and display weight and BMI charts. Unfortunately, few EHRs support physician's obesity-related care and there is low level of obesity-related sophistication in EHRs as recently published.[33]

It is also concerning that rates of weight counseling in primary care have significantly declined despite increased rates of overweight and obesity.[11,12,15] Given that physicians' advice about health risk interventions has been shown to have positive effects on patient risk status, it is important that PCPs do not overlook this rapidly increasing health problem. However, it remains unclear whether an increased recognition of obesity as a disease across the spectrum of providers (including both PCPs and specialists), and appropriate documentation within the EHR of this condition, will translate into an earlier referral to an obesity specialist so appropriate obesity therapy could be initiated. Further investigation is ongoing to address this important issue, which hopefully will facilitate the initiation of obesity therapy in our patients who suffer this condition.

Certain limitations of the current study should be noted. First, it was a cross-sectional study, although it utilized one of the largest EHR data repositories in the world. Second, the prevalence of overweight and obesity noted in our patient population was higher than those estimated in the general US population.[19,20] This circumstance might reflect some population bias because the dataset was limited to individuals seeking health care at the Cleveland Clinic. Thirdly, although the dataset included a very large number of active patients (324,199), they all are part of a single institution.

Conclusions

The results of this report highlight the sobering reality of obesity prevalence and associated comorbidities in the US. Yet despite the high prevalence, underdiagnosis continues to be a significant problem. More than three-quarters of the study population had a BMI consistent with overweight or obesity, but less than half received a formal diagnosis of such via ICD-9 documentation. Underdiagnosis and failing to recognize obesity as a treatable, chronic disease with serious health consequences are important barriers to effective management. Over coming years, we anticipate continued improvements in the documentation of obesity due to increasing therapy coverage by insurance companies, existing reimbursement incentives through the Centers for Medicare and Medicaid Services, and the effective utilization of obesity-related EHR functions. We believe that including obesity in the chronic problem lists of patients with a BMI >30 may be helpful in prompting discussions related to weight-related issues in appropriate individuals. Physicians have a tremendous opportunity to positively impact the health and general well-being of their obese patients if they commit to proactive strategies for diagnosis and intervention.

Contributorship Statement: K.M.P researched and analyzed the data and helped write the manuscript. B.B. and J.B. were involved in the concept and study design, data acquisition, data analysis and interpretation, drafting of initial manuscript, review and revision of the final manuscript, and gave final approval on the manuscript. T.M.H. and R.S.Z. contributed to the discussion and reviewed/edited the article. B.J.W. and A.D.M. researched and analyzed the data, designed the analysis, and contributed to the discussion. S.X.K. and W.W. were involved in concept and study design, data analysis and interpretation, review and revision, and gave final approval on the manuscript. K.M.C. researched and analyzed the data. A.M. extracted, researched, and analyzed the data. B.S. and M.W.K. were involved in concept and study design, data analysis and interpretation, drafting of the manuscript, review and revision of manuscript, and final approval. J.M.B. was involved in the concept and study design, drafting of the manuscript, and project management.

Competing Interests: K.M.P. reports receiving research funding from Novo Nordisk and Merck, receiving consulting fees from Novo Nordisk, and Merck, and receiving honoraria from Merck, AstraZeneca, Sanofi, and Novo Nordisk for speaking/educational activities within the past 12 months. R.S.Z. reports receiving research funding from Novo Nordisk and Merck, and receiving speaker honoraria from Merck, and received consulting fees from Novo Nordisk and Merck within the past 12 months. B.J.W., M.W.K., A.M., K.M.C, and J.M.B. report receiving research funding from Novo Nordisk and Merck within the past 12 months. A.D.M. received research support from the Merck Investigator Studies Program and the Agency for Healthcare Research and Quality K98 HS024128. J.B. and B.S. were employees at Novo Nordisk and owned company stock while the research was being conducted. T.M.H, S.X.K., and W.W. are employees of Novo Nordisk and own company stock. B.B. reports receiving consulting fees and research support from Novo Nordisk in the past 12 months.

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Table 1. Study Population Characteristics

		Body Mass Index (kg/m^2)				
Variable	N (%) or Median (IQR)	<25[b]	25-29.9	30-34.9 (I)[c]	35-39.9 (II)[c]	≥40 (III)[c]
All Subjects	324,199 (100.0%)	68,424 (21.1%)	121,287 (37.4%)	75,199 (23.2%)	34,152 (10.5%)	25,137 (7.8%)
Age (years)[a]	52 (40, 63)	48 (32, 61)	54 (42, 65)	54 (43, 64)	52 (41, 62)	49 (38, 59)
Weight (lbs)[a]	185 (155, 218)	133 (120, 148)	177 (160, 194)	207 (188, 227)	234 (214, 257)	278 (250, 310)
Gender (n,%)						
Male	150,458 (46.4%)	20,340 (29.7%)	66,164 (54.6%)	40,092 (53.3%)	15,116 (44.3%)	8,746 (34.8%)
Female	173,736 (53.6%)	48,083 (70.3%)	55,121 (45.4%)	35,107 (46.7%)	19,034 (55.7%)	16,391 (65.2%)
Missing	5 (0.0%)					
Race (n,%)						
Caucasian (non-Hispanic)	251,028 (77.4%)	54,534 (81.4%)	95,779 (80.1%)	57,548 (77.4%)	25,392 (75.0%)	17,775 (71.2%)
African American	41,789 (12.9%)	5,193 (7.7%)	13,253 (11.1%)	11,242 (15.1%)	6,264 (18.5%)	5,837 (23.4%)
Hispanic	11,799 (3.6%)	3,425 (5.1%)	4,586 (3.8%)	2387 (3.2%)	913 (2.7%)	488 (2.0%)
Asian/PI	4,670 (1.4%)	2,222 (3.3%)	1,759 (1.5%)	505 (0.7%)	130 (0.4%)	54 (0.2%)
Other	10,449 (3.2%)	1,661 (2.5%)	4,158 (3.5%)	2,663 (3.6%)	1,144 (3.4%)	823 (3.3%)
Missing	4,464 (1.4%)					
Smoking Status (n,%)						
Current	48,128 (14.8%)	11,295 (16.6%)	17,071 (14.1%)	11,019 (14.7%)	4,987 (14.6%)	3,756 (15.0%)
Former	96,633 (39.8%)	15,214 (22.3%)	37,899 (31.3%)	24,607 (32.8%)	11,094 (32.6%)	7,819 (31.2%)
Never	178,677 (55.1%)	41,707 (61.1%)	66,081 (54.6%)	39,404 (52.5%)	17,996 (52.8%)	13,489 (53.8%)
Missing	761 (0.2%)					
Median Household Income[a] (US$)	59,420 (43,640, 79,680)	62,210 (47,280, 82,120)	62,500 (45,440, 83,280)	58,300 (42,660, 77,790)	53,890 (39,710, 73,040)	49,940 (35,690, 66,320)
Missing (n,%)	4,319 (1.3%)					
ICD-9 Code for Obesity (%)[d]	76,777 (23.7%)	145† (0.2%)	12,576 (10.4%)	26,185 (34.8%)	18,934 (55.4%)	18,937 (75.3%)
278.0x ONLY	67,848 (88.4%)	136 (93.8%)	11,817 (94.0%)	21,477 (82.0%)	16,034 (84.7%)	18,384 (97.1%)

V85.3x or V85.4x	3,519 (4.6%)	7 (4.8%)	381 (3.0%)	2,162 (8.3%)	878 (2.5%)	91 (0.5%)
278.0x & V85.3x or V85.4x	5,410 (7.0%)	2 (1.4%)	378 (3.0%)	2,546 (9.7%)	2,022 (10.7%)	462 (2.4%)

[a] Median (interquartile range)

[b] 0.2% of subjects had ICD-9 codes for obesity for a median of 2.6 years prior to July 1, 2015

[c] Obesity Class

[d] ICD-9 codes indicating obesity diagnosis

V85 codes indicate the extent of obesity; i.e., V85.3x = BMI 30-39.9, V85.4x = BMI $\geq$ 40
All measured associations between the weight classifications and the patient characteristics were statistically significant with a P-value <0.0001
IQR, interquartile range; PI, Pacific Islander

Table 2. Comorbidities, Vital Statistics and Laboratory Measurements Among Patients, Stratified by BMI Category

Variable	N (%) or Median (IQR)	Body Mass Index (kg/m^2)				
		<25	25-29.9	30-34.9 (I)[b]	35-39.9 (II)[b]	≥40 (III)[b]
All Subjects	324,199 (100.0%)	68,424 (21.1%)	121,287 (37.4%)	75,199 (23.2%)	34,152 (10.5%)	25,137 (7.8%)
Diabetes	49,346 (15.2%)	3,063 (4.5%)	15,196 (12.5%)	14,542 (19.3%)	8,779 (25.7%)	7,766 (30.9%)
Pre-Diabetes	33,130 (10.2%)	602 (0.9%)	12,886 (10.6%)	10,319 (13.7%)	5,087 (14.9%)	4,236 (16.9%)
Hypertension	138,874 (42.8%)	15,854 (23.2%)	49,460 (40.8%)	38,558 (51.3%)	19,435 (56.9%)	15,567 (61.9%)
SBP (mm Hg)[a]	124 (114, 135)	118 (108, 128)	124 (114, 134)	126 (118, 137)	128 (120, 138)	130 (120, 140)
Missing	156 (0.0%)					
DBP (mm Hg)[a]	77 (70, 83)	72 (66, 80)	77 (70, 82)	79 (71, 84)	80 (72, 85)	80 (72, 86)
Missing	158 (0.0%)					
LDL (mg/dL)[a]	104 (84, 126)	99 (80, 120)	106 (85, 128)	106 (85, 128)	105 (84, 127)	104 (84, 124)
Missing, n (%)	60,448 (18.6%)					
HDL (mg/dL)[a]	52 (42, 65)	65 (53, 79)	53 (44, 64)	48 (40, 58)	46 (38, 56)	45 (38, 55)
Missing	55,634 (17.2%)					
Triglycerides (mg/dL)[a]	99 (70, 144)	74 (56, 102)	97 (69, 139)	114 (80, 164)	119 (85, 169)	117 (84, 165)
Missing	56,398 (17.4%)					
Fasting blood glucose (mg/dL)[a, c]	93 (86, 103)	88 (82, 94)	97.5 (93, 101)	103.1 (95, 106)	107 (97, 111)	109.8 (97, 114)
Missing	177,139 (54.6%)					
Random blood glucose (mg/dL)[a]	92 (84, 103)	88 (81, 95)	92 (85, 101)	95 (86, 106)	96 (86, 111)	97 (86, 114)
Missing	54,907 (16.9%)					
Glomerular Filtration Rate[d]	87.4 (73.5, 100.2)	92.0 (78.2, 105.1)	85.4 (72.1, 97.9)	85.4 (71.8, 98.0)	87.8 (73.2, 100.4)	91.5 (76.1, 104.6)
Missing	29,061 (9.0%)					
HbA1c (%)[a]	5.8 (5.5, 6.5)	5.6 (5.3, 5.9)	5.8 (5.5, 6.3)	5.9 (5.6, 6.6)	6.0 (5.6, 6.8)	6.0 (5.7, 6.9)
Missing	207,248 (63.9%)					
Cerebrovascular Disease	22,436 (6.9%)	4,120 (6.0%)	9,002 (7.4%)	5,465 (7.3%)	2,357 (6.9%)	1,492 (5.9%)
Coronary Artery Disease	17,026 (5.3%)	2,210 (3.2%)	6,912 (5.7%)	4,769 (6.3%)	1,946 (5.7%)	1,189 (4.7%)
Heart Failure[e]	5,500 (1.7%)	994 (1.5%)	1,801 (1.5%)	1,368 (1.8%)	741 (2.2%)	596 (2.4%)

DBP, diastolic blood pressure; HDL, high density lipoprotein; IQR, interquartile range; LDL, low density lipoprotein; SBP, systolic blood pressure

[a] Median (interquartile range)

[b] Obesity class

[c] Determination of "fasting" blood glucose: serum blood glucose obtained at the same time of those who had recorded fasting hours

[d] Glomerular Filtration Rate calculated via CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration)

[e] Heart failure recorded prior to 7/1/2013

Diabetes included patients with ICD-9 codes for Type 1 or Type 2 Diabetes.

Pre-diabetes defined as having appropriate ICD-9 code within 2 years + 1 fasting glucose 100mg/dL-125mg/dL or at least 2 fasting glucose measurements of 100mg/dL-125mg/dL, or HbA1c 5.7%-6.4%

Peripheral vascular disease was not included because it is inconsistently defined and not well-documented in medical records.

All measured associations between the weight classifications and the patient characteristics were statistically significant with a P-value <0.0001

Table 3. Hypertension and Hyperlipidemia Medication Usage Among Patients, Stratified by BMI category

	Total	Body Mass Index (kg/m^2)				
Variable	N (%)	<25	25-29.9	30-34.9	35-39.9	≥40
All Subjects	324,199 (100.0%)	68,424 (21.1%)	121,287 (37.4%)	75,199 (23.2%)	34,152 (10.5%)	25,137 (7.8%)
HTN Medication	120,993 (37.3%)	13,345 (19.5%)	43,014 (35.5%)	33,774 (44.9%)	17,219 (50.4%)	13,641 (54.3%)
Number of classes of HTN medications, median (IQR)	0 (0, 2)	0 (0, 0)	0 (0, 2)	0 (0, 2)	1 (0, 2)	1 (0, 2)
Cholesterol Lowering Medications	83,637 (25.8%)	8,288 (12.1%)	33,802 (27.9%)	23,982 (31.9%)	10,626 (31.1%)	6,939 (27.6%)
Statin + second drug (non-statin)*	8,915 (2.7%)	646 (0.9%)	3,586 (3.0%)	2,698 (3.6%)	1,264 (3.7%)	721 (2.9%)
Statin only	69,071 (21.3%)	6,921 (10.1%)	28,068 (23.1%)	19,696 (26.2%)	8,657 (25.3%)	5,729 (22.8%)
Non-statin drug only	5,651 (1.7%)	721 (1.1%)	2,148 (1.9%)	1,588 (1.8%)	705 (2.1%)	489 (2.1%)

*Non-statin cholesterol lowering medications included bile acid sequestrants, fibrates, and other dyslipidemia drugs that comprise a variety of different mechanisms of action

All measured associations between the weight classifications and the patient characteristics were statistically significant with a P-value <0.0001

HTN, hypertension; IQR, interquartile range

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Prevalence and Recognition of Obesity and its Associated Comorbidities in a Large U.S. Integrated Health System

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ABSTRACT

Objective: To determine the prevalence of obesity and its related comorbidities among patients being actively managed at a U.S. academic medical center, and to examine the frequency of a formal diagnosis of obesity, via ICD-9 documentation among patients with BMI $\geq$30 kg/m^2.

Design: The electronic health record system at Cleveland Clinic was used to create a cross-sectional summary of actively-managed patients meeting minimum primary care physician visit frequency requirements. Eligible patients were stratified by BMI categories, based on most recent weight and median of all recorded heights obtained on or before the index date of July 1, 2015. Relationships between patient characteristics and BMI categories were tested.

Setting: A large U.S. integrated health system

Results: A total of 324,199 active patients with a recorded BMI were identified. There were 121,287 (37.4%) patients found to have overweight (BMI ≥25 and < 29.9), 75,199 (23.2%) had BMI 30-34.9, 34,152 (10.5%) had BMI 35-39.9 and 25,137 (7.8%) had BMI ≥40. There was a higher prevalence of T2D, prediabetes, hypertension and cardiovascular disease (P-value <0.0001) within higher BMI compared to lower BMI categories. In patients with a BMI > 30 (N = 134,488), only 48% (64,056) had documentation of an obesity ICD-9 code. In those patients with a BMI > 40, only 75% had an obesity ICD-9 code.

Conclusions: This cross-sectional summary from a large U.S. integrated health system, found that 3 out of every 4 patients had overweight or obesity based on BMI. Patients within higher BMI categories had a higher prevalence of comorbidities. Less than half of patients who were identified as having obesity according to BMI received a formal diagnosis via ICD-9 documentation. The disease of obesity is very prevalent yet underdiagnosed in our clinics. The under diagnosing of obesity may serve as an important barrier to treatment initiation.

Article Summary

Strengths and Limitations of this study:

- The analysis included a very large sample of 324,199 patients with recorded BMI values.
- The electronic health records (EHR) used for the study (Cleveland Clinic) provide a rich source of demographic, clinical, laboratory, and prescription data on patients.
- Overweight and obesity categorizations were based on actual BMI calculations, not ICD coding.
- As a potential limitation, all patients were identified from a single institution's EHR, albeit one of the largest in the world (Cleveland Clinic).

- Another limitation is that all subjects were individuals seeking healthcare services, thus possibly not representative of the broader U.S. population.

Introduction

Obesity represents a major public health problem in the United States from the dual aspects of prevalence and consequence. The prevalence of obesity in the United States has nearly tripled over past decades, increasing from 13% in 1960–1962 to 36.5% during 2011–2014,[1] thus affecting an estimated 60 million American adults. Obesity is associated with a number of important chronic diseases such as type 2 diabetes (T2D), hypertension (HTN), dyslipidemia, coronary heart disease, stroke, several cancers, disability, and increased mortality.[2-7]

The U.S. Preventive Services Task Force (USPSTF) recommends screening all adults for obesity,[8] recognizing that health care providers have an important role in preventing, identifying and managing this chronic disease. The USPSTF also recommends that once a diagnosis of obesity has been established, physicians should offer or refer patients with a body mass index (BMI) ≥30 kg/m^2 to an intensive, interdisciplinary lifestyle intervention program.[8]

Despite these recommendations and formal recognition by the American Medical Association as a disease,[9] obesity continues to be underdiagnosed in clinical practice.[10] It is estimated that less than 30% of adults with obesity receive this diagnosis during their primary care physician (PCP) visit.[10] Furthermore, some data suggest that weight counseling as a component of primary healthcare services in the US has been declining significantly over the past decade.[11,12] Yet, obesity screening and recognition of obesity as a complex, chronic diagnosis are among the first steps leading to effective treatment[13]. Obesity-related electronic health records have been highlighted as a useful tool to assist health care providers in the screening and management of obesity.[14-17]

The primary objective of the present study was to determine the true prevalence of obesity and related comorbidities among patients being actively managed at the Cleveland Clinic using EHR data. A secondary goal was to evaluate how frequently a formal diagnosis of obesity, via ICD-9 coding, was documented among patients with a BMI ≥ 30 kg/m^2.

Methods

The enterprise-wide electronic health record (EHR) system at Cleveland Clinic was used to create a cross-sectional summary of actively-managed patients, stratified by BMI categories, as of July 1, 2015. All Cleveland Clinic facilities utilize the MyPractice EHR system, composed of an integrated suite of software modules created by Epic® Systems (Verona, WI), and which was first installed in 1998. The EHR includes patient demographics, social, medical, family and surgical history, vital signs, imaging data and pathology reports, and rich longitudinal clinical data (diagnosis, procedures, etc.) from both the inpatient and outpatient records. It contains discrete data linkage with Cleveland Clinic laboratory records, as well as detailed medication usage information. In 2014, Cleveland Clinic set a new annual record for outpatient visits (almost 6 million), and has >1 million active patients (2 or more encounters within the past 12 months).

Patients were included if they were ≥20 years of age on the index date (as they may not have reached their full height by 18 years of age). Patients were considered "actively managed" and included in the analysis if they had been seen by a PCP at least 3 times prior to the index date, with at least one of the visits having occurred within the immediate 18 months preceding the index date. Patients were excluded for any of the following reasons: median height <4'6" or >7'6"; weight >750 lbs (340 kg); pregnant or having recently given birth; amputees; diagnosis of HIV prior to the index date; diagnosis of hyperthyroidism, hypothyroidism, heart failure, radiation or chemotherapy treatment, or metastatic cancer between July 1st, 2013 and the index date (July 1st, 2015).

BMI calculations were determined using the most recent weight and median of all recorded heights obtained on or before the index date (July 1, 2015). The weight recorded closest to the index date was recorded as the study weight. Height and weight measures were obtained from outpatient encounters excluding ophthalmology, orthopedic, and psychiatry specialty visits because of a lack of precision of height and weight measurements obtained at these encounters. Income was defined as the five-year estimates (2008-2012) of median household income at the block group level obtained from the American Community Survey conducted by the U.S. Census Bureau.[18] The census block group was obtained by geocoding the patient address that was on file closest to baseline. BMI, weight, and smoking status were defined as the value recorded in the EHR closest to baseline (but without any time restrictions). Demographic and laboratory/vital sign data were recorded based on the most recent values available in the EHR on or before the index date. Comorbidities were identified in the EHR anytime up until the index date. Obesity diagnosis was based on ICD-9 code 278.0x and V-codes V85.3x and V85.4x.

Relationships between patient characteristics and weight classifications (BMI categories) were tested using univariate analysis, where chi-square was used for testing the association between the weight classifications and a categorical characteristic. The non-parametric Kruskal-Wallis test was used for continuous characteristics.

This study was approved by the Cleveland Clinic's Institutional Review Board.

Results

As of July 1st, 2015, a total of 324,199 active patients with a recorded BMI were identified to meet the inclusion/exclusion criteria (Figure 1). Of these, 255,775 (78.9%) patients met criteria for overweight or obesity according to their recorded BMI: 121,287 (37.4%) were found to be overweight, 75,199 (23.2%) had obesity class I (BMI 30-34.9), 34,152 (10.5%) had obesity class II (BMI 35-39.9) and 25,137 (7.8%) had obesity class III (BMI ≥40). The median time from July 1st, 2015 until the closest measurement of BMI was 4.7 months (interquartile range [IQR]: 1.9 to 13.2 months) for all 324,199 patients. The median time from July 1st, 2015 until the closest measurement of BMI for those with a BMI ≥ 25 (n = 255,775) and for BMI < 25 (68,424), was 4.4 months (IQR: 1.8, 9.4) and 6 months (IQR: 2.3, 11.9), respectively.

All measured associations between the weight classifications and the patient characteristics were statistically significant (P<0.0001).

Table 1. Study Population Characteristics

		Body Mass Index (kg/m^2)				
Variable	N (%) or Median (IQR)	<25[b]	25-29.9	30-34.9 (I)[c]	35-39.9 (II)[c]	≥40 (III)[c]
All Subjects	324,199 (100.0%)	68,424 (21.1%)	121,287 (37.4%)	75,199 (23.2%)	34,152 (10.5%)	25,137 (7.8%)
Age (years)[a]	52 (40, 63)	48 (32, 61)	54 (42, 65)	54 (43, 64)	52 (41, 62)	49 (38, 59)
Weight (lbs)[a]	185 (155, 218)	133 (120, 148)	177 (160, 194)	207 (188, 227)	234 (214, 257)	278 (250, 310)
Gender (n, column %; *row %*)						
Male	150,458 (46.4%)	20,340 (29.7%) *(13.5%)*	66,164 (54.6%) *(44.0%)*	40,092 (53.3%) *(26.6%)*	15,116 (44.3%) *(10.0%)*	8,746 (34.8%) *(5.8%)*
Female	173,736 (53.6%)	48,083 (70.3%) *(27.7%)*	55,121 (45.4%) *(31.2%)*	35,107 (46.7%) *(20.2%)*	19,034 (55.7%) *(11.0%)*	16,391 (65.2%) *(9.4%)*
Missing	5 (0.0%)					
Race (n, column %; *row %*)						
Caucasian (non-Hispanic)	251,028 (77.4%)	54,534 (81.4%) *(21.7%)*	95,779 (80.1%) *(38.2)*	57,548 (77.4%) *(22.9%)*	*25,392 (75.0%)* *(10.1%)*	17,775 (71.2%) *(7.1%)*
African American	41,789 (12.9%)	5,193 (7.7%) *(12.4%)*	13,253 (11.1%) *(31.7%)*	11,242 (15.1%) *(26.8%)*	6,264 (18.5%) *(15.0%)*	5,837 (23.4%) *(14.0%)*
Hispanic	11,799 (3.6%)	3,425 (5.1%) *(29.0%)*	4,586 (3.8%) *(38.9%)*	2387 (3.2%) *(20,1%)*	913 (2.7%) *(7.7%)*	488 (2.0%) *(4.1%)*
Asian/PI	4,670 (1.4%)	2,222 (3.3%) *(47.6%)*	1,759 (1.5%) *(37.7%)*	505 (0.7%) *(10.8%)*	130 (0.4%) *(2.8%)*	54 (0.2%) *(1.2%)*
Other	10,449 (3.2%)	1,661 (2.5%) *(15.9%)*	4,158 (3.5%) *(39.8%)*	2,663 (3.6%) *(25.5%)*	1,144 (3.4%) *(10.9%)*	823 (3.3%) *(7.9%)*
Missing	4,464 (1.4%)					
Smoking Status (n, column %; *row %*)						
Current	48,128 (14.8%)	11,295 (16.6%) *(23.5%)*	17,071 (14.1%) *(35.5%)*	11,019 (14.7%) *(22.9%)*	4,987 (14.6%) *(10.4%)*	3,756 (15.0%) *(7.8%)*
Former	96,633 (39.8%)	15,214 (22.3%) *(15.7%)*	37,899 (31.3%) *(39.2%)*	24,607 (32.8%) *(25.5%)*	11,094 (32.6%) *(11.5%)*	7,819 (31.2%) *(8.1%)*
Never	178,677 (55.1%)	41,707 (61.1%) *(23.3%)*	66,081 (54.6%) *(37.0%)*	39,404 (52.5%) *(22.1%)*	17,996 (52.8%) *(10.1%)*	13,489 (53.8%) *(7.5%)*

Missing	761 (0.2%)					
Median Household Income[a] (US$)	59,420 (43,640, 79,680)	62,210 (47,280, 82,120)	62,500 (45,440, 83,280)	58,300 (42,660, 77,790)	53,890 (39,710, 73,040)	49,940 (35,690, 66,320)
Missing (n,%)	4,319 (1.3%)					
ICD-9 Code for Obesity (%)[d]	76,777 (23.7%)	145b(0.2%)	12,576 (10.4%)	26,185 (34.8%)	18,934 (55.4%)	18,937 (75.3%)
278.0x ONLY	67,848 (88.4%)	136 (93.8%)	11,817 (94.0%)	21,477 (82.0%)	16,034 (84.7%)	18,384 (97.1%)
V85.3x or V85.4x	3,519 (4.6%)	7 (4.8%)	381 (3.0%)	2,162 (8.3%)	878 (2.5%)	91 (0.5%)
278.0x & V85.3x or V85.4x	5,410 (7.0%)	2 (1.4%)	378 (3.0%)	2,546 (9.7%)	2,022 (10.7%)	462 (2.4%)

[a] Median (interquartile range)

[b] 0.2% of subjects had ICD-9 codes for obesity for a median of 2.6 years prior to July 1, 2015

[c] Obesity Class

[d] ICD-9 codes indicating obesity diagnosis

V85 codes indicate the extent of obesity; i.e., V85.3x = BMI 30-39.9, V85.4x = BMI $\geq$ 40

All measured associations between the weight classifications and the patient characteristics were statistically significant with a P-value <0.0001

IQR, interquartile range; PI, Pacific Islander

Study Population

Table 1 provides study population characteristics and demographics. The median (IQR) age for the entire population was 52 years (40, 63) and the slight majority of patients were female (54%). The population included Caucasians (77.4%), African-Americans (12.9%), Hispanics (3.6%) and Asian/Pacific Islanders (1.4%).

Based on height and weight measurements, 78.9% of the patients had BMI values classified as overweight or obesity. For obesity class I (BMI 30-34.9), a higher percentage were males (53%), unlike patients with BMI <25 (30%) or obesity class II and III (44% and 35%, respectively). There was a significantly smaller percentage of males than females within the obesity class III category (35% males vs. 65% females, respectively).

The proportion of African-American individuals in increased as BMIcategory increased, while this pattern was not observed for other races.

The prevalence of smoking was similar among the various BMI categories compared to individuals with normal BMI.

As BMI category increased, median household income decreased, as determined by census block group of residence. The median household income (in US $) stratified by BMI category was: $62,210 (BMI <25); $62,500 (BMI 25-29.9); $58,300 (BMI 30-34.9); $53,890 (BMI 35-39.9); and $49,940 (BMI ≥40).

Documentation of an ICD-9 Code for Obesity. Out of 134,488 patients with a BMI ≥30, 48% (n=64,056) had a documented ICD-9 code for a diagnosis of obesity (ICD-9: 278.0x, V85.3x, V85.4x). Among patients with a BMI ≥40 (n=25,137), 75% (n=18,937) had an ICD-9 code for a diagnosis of obesity. In all 3 obesity classes, only a minority had a V85.x code for obesity class.

Table 2. Comorbidities, Vital Statistics and Laboratory Measurements Among Patients, Stratified by BMI Category

Variable	N (%)[a] or Median (IQR)	Body Mass Index (kg/m^2) N (%)[a] or Median (IQR) <25	25-29.9	30-34.9 (I)[c]	35-39.9 (II)[c]	≥40 (III)[c]
All Subjects (% within row)	324,199 (100.0%)	68,424 (21.1%)	121,287 (37.4%)	75,199 (23.2%)	34,152 (10.5%)	25,137 (7.8%)
Diabetes	49,346 (15.2%)	3,063 (4.5%)	15,196 (12.5%)	14,542 (19.3%)	8,779 (25.7%)	7,766 (30.9%)
Pre-Diabetes	33,130 (10.2%)	602 (0.9%)	12,886 (10.6%)	10,319 (13.7%)	5,087 (14.9%)	4,236 (16.9%)
Hypertension	138,874 (42.8%)	15,854 (23.2%)	49,460 (40.8%)	38,558 (51.3%)	19,435 (56.9%)	15,567 (61.9%)
SBP (mm Hg)[b]	124 (114, 135)	118 (108, 128)	124 (114, 134)	126 (118, 137)	128 (120, 138)	130 (120, 140)
Missing	156 (0.0%)					
DBP (mm Hg)[b]	77 (70, 83)	72 (66, 80)	77 (70, 82)	79 (71, 84)	80 (72, 85)	80 (72, 86)
Missing	158 (0.0%)					
LDL (mg/dL)[b]	104 (84, 126)	99 (80, 120)	106 (85, 128)	106 (85, 128)	105 (84, 127)	104 (84, 124)
Missing, n (%)	60,448 (18.6%)					
HDL (mg/dL)[b]	52 (42, 65)	65 (53, 79)	53 (44, 64)	48 (40, 58)	46 (38, 56)	45 (38, 55)
Missing	55,634 (17.2%)					
Triglycerides (mg/dL)[b]	99 (70, 144)	74 (56, 102)	97 (69, 139)	114 (80, 164)	119 (85, 169)	117 (84, 165)
Missing	56,398 (17.4%)					
Fasting blood glucose (mg/dL)[b, d]	93 (86, 103)	88 (82, 94)	97.5 (93, 101)	103.1 (95, 106)	107 (97, 111)	109.8 (97, 114)
Missing	177,139 (54.6%)					
Random blood glucose (mg/dL)[b]	92 (84, 103)	88 (81, 95)	92 (85, 101)	95 (86, 106)	96 (86, 111)	97 (86, 114)
Missing	54,907 (16.9%)					
Glomerular Filtration [e]	87.4 (73.5, 100.2)	92.0 (78.2, 105.1)	85.4 (72.1, 97.9)	85.4 (71.8, 98.0)	87.8 (73.2, 100.4)	91.5 (76.1, 104.6)
Missing	29,061 (9.0%)					
HbA1c (%)[b]	5.8 (5.5, 6.5)	5.6 (5.3, 5.9)	5.8 (5.5, 6.3)	5.9 (5.6, 6.6)	6.0 (5.6, 6.8)	6.0 (5.7, 6.9)
Missing	207,248 (63.9%)					

Cerebrovascular Disease	22,436 (6.9%)	4,120 (6.0%)	9,002 (7.4%)	5,465 (7.3%)	2,357 (6.9%)	1,492 (5.9%)
Coronary Artery Disease	17,026 (5.3%)	2,210 (3.2%)	6,912 (5.7%)	4,769 (6.3%)	1,946 (5.7%)	1,189 (4.7%)
Heart Failure[f]	5,500 (1.7%)	994 (1.5%)	1,801 (1.5%)	1,368 (1.8%)	741 (2.2%)	596 (2.4%)

DBP, diastolic blood pressure; HDL, high density lipoprotein; IQR, interquartile range; LDL, low density lipoprotein; SBP, systolic blood pressure

[a] Except for "All Subjects" row, percentages reflect % within column (BMI) category

[b] Median (interquartile range)

[c] Obesity class

[d] Determination of "fasting" blood glucose: serum blood glucose obtained at the same time of those who had recorded fasting hours

[e] Glomerular Filtration Rate calculated via CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration)

[f] Heart failure recorded prior to 7/1/2013

Diabetes included patients with ICD-9 codes for Type 1 or Type 2 Diabetes.

Pre-diabetes defined as having appropriate ICD-9 code within 2 years + 1 fasting glucose 100mg/dL-125mg/dL or at least 2 fasting glucose measurements of 100mg/dL-125mg/dL, or HbA1c 5.7%-6.4%

Peripheral vascular disease was not included because it is inconsistently defined and not well-documented in medical records.

All measured associations between the weight classifications and the patient characteristics were statistically significant with a P-value <0.0001

Comorbidities

Table 2 presents data on comorbidity patterns in the study population, stratified by BMI category. The proportion of patients with diabetes or pre-diabetes rose with increasing BMI category. The prevalence of T2D and prediabetes within BMI categories increased from 4.5% and 0.9%, respectively of the BMI < 25 category to 30.9% and 16.9%, respectively, in the BMI ≥40 category. The rate of accurate ICD-9 coding for obesity among patients with T2D and BMI ≥30 was 59.3% (18,436/31,087), notably higher than among patients without T2D and having a BMI ≥30 (44.1%; 45,620/103,401).

The proportions of patients with HTN was also observed to rise with increasing BMI category, and both median systolic and diastolic blood pressures (BP, mmHg) increased with escalating BMI category.

There was no clinically meaningful difference in the median levels of LDL cholesterol (mg/dL) among the different BMI categories. Median HDL cholesterol levels were observed to decline with increasing BMI category. Median triglyceride levels increased from 74 mg/dL in the BMI <25 category to 119 mg/dL in the BMI 35-39.9 category, then appeared to plateau.

Patients with BMI ≥25 had a slightly higher prevalence of coronary artery disease compared to individuals with BMI <25, but no clinically meaningful differences in the prevalence of heart failure were observed between the BMI categories. There were no significant differences in the prevalence of cerebrovascular disease or glomerular filtration rate [calculated via CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration)] among the different groups of patients with obesity compared to lean subjects.

Glycemic control. The median fasting blood glucose values in individuals classified as overweight and obese were higher compared with patients with BMI <25 (**Table 2**). Median HbA1c values and random blood glucose measures for patients with overweight and obesity were marginally higher than in patients with BMI <25.

Table 3. Hypertension and Hyperlipidemia Medication Usage Among Patients, Stratified by BMI category

	Total	Body Mass Index (kg/m^2)				
Variable	N (%)	<25	25-29.9	30-34.9	35-39.9	≥40
All Subjects	324,199 (100.0%)	68,424 (21.1%)	121,287 (37.4%)	75,199 (23.2%)	34,152 (10.5%)	25,137 (7.8%)
HTN Medication	120,993 (37.3%)	13,345 (19.5%)	43,014 (35.5%)	33,774 (44.9%)	17,219 (50.4%)	13,641 (54.3%)
Number of classes of HTN medications, median (IQR)	0 (0, 2)	0 (0, 0)	0 (0, 2)	0 (0, 2)	1 (0, 2)	1 (0, 2)
Cholesterol Lowering Medications	83,637 (25.8%)	8,288 (12.1%)	33,802 (27.9%)	23,982 (31.9%)	10,626 (31.1%)	6,939 (27.6%)
Statin + second drug (non-statin)*	8,915 (2.7%)	646 (0.9%)	3,586 (3.0%)	2,698 (3.6%)	1,264 (3.7%)	721 (2.9%)
Statin only	69,071 (21.3%)	6,921 (10.1%)	28,068 (23.1%)	19,696 (26.2%)	8,657 (25.3%)	5,729 (22.8%)
Non-statin drug only	5,651 (1.7%)	721 (1.1%)	2,148 (1.9%)	1,588 (1.8%)	705 (2.1%)	489 (2.1%)

*Non-statin cholesterol lowering medications included bile acid sequestrants, fibrates, and other dyslipidemia drugs that comprise a variety of different mechanisms of action

All measured associations between the weight classifications and the patient characteristics were statistically significant with a P-value <0.0001

HTN, hypertension; IQR, interquartile range

Medications. As shown in **Table 3**, HTN medication utilization rose with increasing BMI categories from 19.5% in the lowest BMI category (<25) to 54.3% in the highest BMI category (≥40). Also, 30.8% of patients with obesity (BMI >30) were using a medication to control their cholesterol, whereas only 12.1% of lean subjects (BMI <25) were taking lipid-lowering medications (all P<0.0001). Patients with obesity were also more likely to be using a second lipid-lowering medication in addition to a statin.

Discussion

In this robust analysis of EHR data from the Cleveland Clinic, BMI values for almost 80% of patients fell with categories of overweight (37.4%) or obesity (41.5%). Thus, only about one in five patients had a BMI that was not indicative of overweight or obesity. The prevalence of overweight/obesity in this population (78%) is somewhat higher than estimated recently for the general US population; just over two-thirds (69%) of adults were estimated to be overweight or obese in the US between 2009-2012.[19,20] This observation could be, in part, because the population seeking medical care at our institution may be sicker, whereas the number reported through National Center for Health Statistics is self-reported/survey based.

Data from the National Health and Nutrition Examination Survey[1] demonstrated that the prevalence of obesity was 36.5% among U.S. adults during 2011–2014. The prevalence of obesity was noted to be higher in women and among non-Hispanic black and Hispanics. Consistent with these data, we identified a higher percentage of females compared with males among obesity classes II and III in our patient population. Higher rates of obesity diagnosis in female patients have been theoretically attributed to more frequent healthcare utilization by women in general or sex bias on the part of providers.[21] However, the current study was based on objective BMI data, thus sex bias was clearly not a factor. While the percentage of female patients was slightly higher than that of male patients in the overall study population, the ratio of female to male subjects in the highest BMI categories was greater. We also identified a higher prevalence of African-Americans and a lower median household income within the higher BMI categories. While the median age appeared to be relatively constant across BMI categories, when BMI classifications were stratified by categorical age groupings (data not shown), higher rates of BMI > 25 and > 30 were observed with increasing age category.

Diabetes is another global health epidemic that is driven largely by rising obesity rates.[22] Excess body fat increases the risk for prediabetes; men and women with obesity, respectively, have a 7-fold and 12-fold higher risk for developing T2D.[23] In the current dataset, 15% of the entire study population had a diagnosis of T2D. This finding corroborates those of a recent report which estimated the prevalence of diabetes among U.S. adults in 2011-2102 to be 12-14%.[24] However, the prevalence of pre-diabetes in the current study population (10%) was markedly lower than reported previously (38%).[24] The Cleveland Clinic employs strict criteria for a diagnosis of pre-diabetes, which may partly explain the discrepancy. We also noticed that patients with higher BMI had higher prevalences of T2D and prediabetes compared to leaner subjects.

Patients with obesity and T2D often have an increased incidence of cardiovascular disease risk factors, such as hypertension and dyslipidemia,[25,26] which is not surprising given that both obesity and T2D are independent risk factors for cardiovascular disease.[25,27] In agreement with these observations, our study found higher prevalences of hypertension and dyslipidemia (per cholesterol-lowering medication utilization) among patients with obesity compared to leaner subjects. We also noted an increased prevalence of coronary artery disease and congestive heart failure in our patients with obesity compared to lean subjects.

The U.S. Preventive Task Force (USPSTF) recommends screening all adults for obesity[8], yet the U.S. healthcare system still faces challenges in this area. The continued lack of recognition of obesity as a disease and under-diagnosis by clinicians postpones the initiation of treatment and increases the risk of developing complications. Body weight is a modifiable risk factor, and weight loss of 5-10% has been shown to improve multiple health outcomes, including cardiovascular risk factors.[28] In patients with obesity and T2D, benefits of weight loss may include improvements in insulin sensitivity, sleep apnea, less depression, less urinary incontinence, reduced need of diabetes medications, improved quality of life, and even lower costs[28,29]. Significant weight loss has even been associated with remission of T2D.[30] Several reasons have been suggested as responsible for why providers are reluctant to include obesity in the list of diagnoses in patients with BMI >30. These include: perception by health care providers that obesity is not a disease, low expectations for patient success, lack of time or knowledge to provide appropriate advice regarding nutrition, societal stigma, concerns with denials of payment for services, and limited therapeutic tools to treat patients with obesity.[12,15,31,32]

Identifying obesity is the first step leading to optimal interdisciplinary intervention ideally involving lifestyle modifications relating to nutrition and physical activity, as well as medications where necessary

to reduce appetite. Optimal obesity-related EHR functions should help to carry out this important task. We took advantage of our institution's EHR functions to document what is probably the most relevant finding of our study. In addition to identifying BMI-defined obesity in more than 40% of our patients, we observed that only half of such patients received a formal diagnosis of obesity via ICD-9 coding (278.00). We did observe that among patients with BMI-defined obesity, the percentage of patients that received a formal obesity diagnosis via ICD-9 documentation was 15% higher among patients with a diagnosis of diabetes compared with those not having a diagnosis of diabetes. This highlights that patients with obesity-related comorbidities like diabetes may be more likely to receive a formal diagnosis of obesity. This observation may be, in part, because patients with diabetes are sicker and are seen more frequently, affording more opportunities for a formal diagnosis of obesity to occur.

Several studies have demonstrated the usefulness of EHR functions for screening and treating obesity, specifically with regard to assessing BMI, diagnosing obesity, and facilitating obesity counseling and treatment services.[16,17,33] In compliance with meaningful use standards, EHRs are required to calculate BMI for all patients, as well as plot and display weight and BMI charts. Unfortunately, few EHRs support physician's obesity-related care and there is low level of obesity-related sophistication in EHRs as recently published.[33] It should be noted that, while BMI categorization is a clinically practical and generally useful means of identifying obesity, BMI is an indirect measure of body fat and has been shown to have high specificity but low sensitivity to identify adiposity.[34] In addition, BMI measurements do not factor in age-related changes in body composition such as increased body fat and decreased muscle mass.[35]

It is also concerning that rates of weight counseling in primary care have significantly declined despite increased rates of overweight and obesity.[11,12,15] Given that physicians' advice about health risk interventions has been shown to have positive effects on patient risk status, it is important that PCPs do not overlook this rapidly increasing health problem. However, it remains unclear whether an increased recognition of obesity as a disease across the spectrum of providers (including both PCPs and specialists), and appropriate documentation within the EHR of this condition, will translate into an earlier referral to an obesity specialist so appropriate obesity therapy could be initiated. Further investigation is ongoing to address this important issue, which hopefully will facilitate the initiation of obesity therapy in our patients who suffer this condition.

Certain limitations of the current study should be noted. First, it was a cross-sectional study, although it utilized one of the largest EHR data repositories in the world. Second, the prevalence of overweight and obesity noted in our patient population was higher than those estimated in the general US population.[19,20] This circumstance might reflect some population bias because the dataset was limited to individuals seeking health care at the Cleveland Clinic. Thirdly, although the dataset included a very large number of active patients (324,199), they all are part of a single institution.

Conclusions

The results of this report highlight the sobering reality of obesity prevalence and associated comorbidities in the US. Yet despite the high prevalence, underdiagnosis continues to be a significant problem. More than three-quarters of the study population had a BMI consistent with overweight or obesity, but less than half received a formal diagnosis of such via ICD-9 documentation. Underdiagnosis and failing to recognize obesity as a treatable, chronic disease with serious health consequences are important barriers to effective management. Over coming years, we anticipate continued improvements in the documentation of obesity due to increasing therapy coverage by insurance companies, existing reimbursement incentives through the Centers for Medicare and Medicaid Services, and the effective utilization of obesity-related EHR functions. We believe that including obesity in the chronic problem lists of patients with a BMI >30 may be helpful in prompting discussions related to weight-related issues in appropriate individuals. Physicians have a tremendous opportunity to positively impact the health and general well-being of their patients with obesity if they commit to proactive strategies for diagnosis and intervention.

Contributorship Statement: K.M.P researched and analyzed the data and helped write the manuscript. B.B. and J.B. were involved in the concept and study design, data acquisition, data analysis and interpretation, drafting of initial manuscript, review and revision of the final manuscript, and gave final approval on the manuscript. T.M.H. and R.S.Z. contributed to the discussion and reviewed/edited the article. B.J.W. and A.D.M. researched and analyzed the data, designed the analysis, and contributed to the discussion. S.X.K. and W.W. were involved in concept and study design, data analysis and interpretation, review and revision, and gave final approval on the manuscript. K.M.C. researched and analyzed the data. A.M. extracted, researched, and analyzed the data. B.S. and M.W.K. were involved in concept and study design, data analysis and interpretation, drafting of the manuscript, review and revision of manuscript, and final approval. J.M.B. was involved in the concept and study design, drafting of the manuscript, and project management.

Competing Interests: K.M.P. reports receiving research funding from Novo Nordisk and Merck, receiving consulting fees from Novo Nordisk, and Merck, and receiving honoraria from Merck, AstraZeneca, Sanofi, and Novo Nordisk for speaking/educational activities within the past 12 months. R.S.Z. reports

receiving research funding from Novo Nordisk and Merck, and receiving speaker honoraria from Merck, and received consulting fees from Novo Nordisk and Merck within the past 12 months. B.J.W., M.W.K., A.M., K.M.C, and J.M.B. report receiving research funding from Novo Nordisk and Merck within the past 12 months. A.D.M. received research support from the Merck Investigator Studies Program and the Agency for Healthcare Research and Quality K08 HS024128. J.B. and B.S. were employees at Novo Nordisk and owned company stock while the research was being conducted. T.M.H, S.X.K., and W.W. are employees of Novo Nordisk and own company stock. B.B. reports receiving consulting fees and research support from Novo Nordisk in the past 12 months.

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Figure Legend

Figure 1. STROBE flow diagram of study population

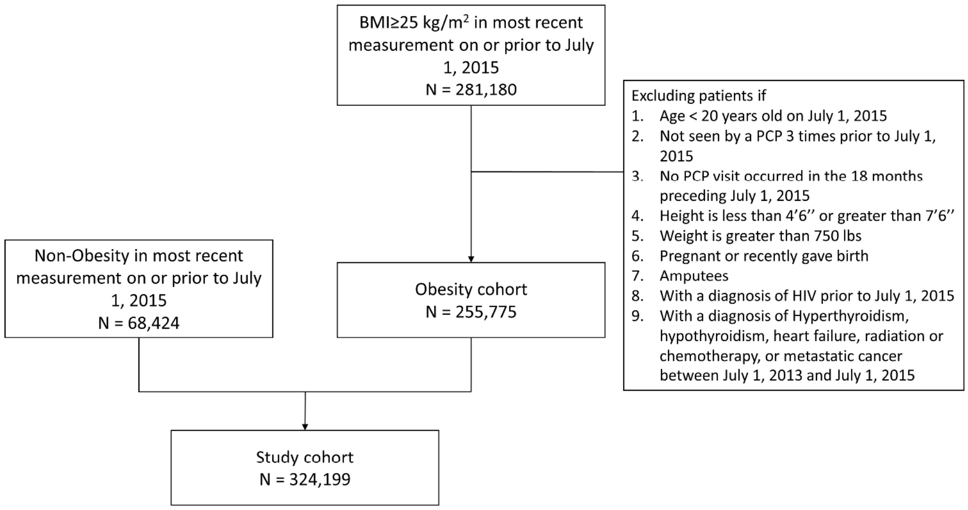

Figure 1

338x190mm (300 x 300 DPI)

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Prevalence and Recognition of Obesity and its Associated Comorbidities in a Large U.S. Integrated Health System

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ABSTRACT

Objective: To determine the prevalence of obesity and its related comorbidities among patients being actively managed at a U.S. academic medical center, and to examine the frequency of a formal diagnosis of obesity, via ICD-9 documentation among patients with BMI $\geq$30 kg/m^2.

Design: The electronic health record system at Cleveland Clinic was used to create a cross-sectional summary of actively-managed patients meeting minimum primary care physician visit frequency requirements. Eligible patients were stratified by BMI categories, based on most recent weight and median of all recorded heights obtained on or before the index date of July 1, 2015. Relationships between patient characteristics and BMI categories were tested.

Setting: A large U.S. integrated health system

Results: A total of 324,199 active patients with a recorded BMI were identified. There were 121,287 (37.4%) patients found to have overweight (BMI ≥25 and < 29.9), 75,199 (23.2%) had BMI 30-34.9, 34,152 (10.5%) had BMI 35-39.9 and 25,137 (7.8%) had BMI ≥40. There was a higher prevalence of T2D, prediabetes, hypertension and cardiovascular disease (P-value <0.0001) within higher BMI compared to lower BMI categories. In patients with a BMI > 30 (N = 134,488), only 48% (64,056) had documentation of an obesity ICD-9 code. In those patients with a BMI > 40, only 75% had an obesity ICD-9 code.

Conclusions: This cross-sectional summary from a large U.S. integrated health system, found that 3 out of every 4 patients had overweight or obesity based on BMI. Patients within higher BMI categories had a higher prevalence of comorbidities. Less than half of patients who were identified as having obesity according to BMI received a formal diagnosis via ICD-9 documentation. The disease of obesity is very prevalent yet underdiagnosed in our clinics. The under diagnosing of obesity may serve as an important barrier to treatment initiation.

Article Summary

Strengths and Limitations of this study:

- The analysis included a very large sample of 324,199 patients with recorded BMI values.
- The electronic health records (EHR) used for the study (Cleveland Clinic) provide a rich source of demographic, clinical, laboratory, and prescription data on patients.
- Overweight and obesity categorizations were based on actual BMI calculations, not ICD coding.
- As a potential limitation, all patients were identified from a single institution's EHR, albeit one of the largest in the world (Cleveland Clinic).

- Another limitation is that all subjects were individuals seeking healthcare services, thus possibly not representative of the broader U.S. population.

Introduction

Obesity represents a major public health problem in the United States from the dual aspects of prevalence and consequence. The prevalence of obesity in the United States has nearly tripled over past decades, increasing from 13% in 1960–1962 to 36.5% during 2011–2014,[1] thus affecting an estimated 60 million American adults. Obesity is associated with a number of important chronic diseases such as type 2 diabetes (T2D), hypertension (HTN), dyslipidemia, coronary heart disease, stroke, several cancers, disability, and increased mortality.[2-7]

The U.S. Preventive Services Task Force (USPSTF) recommends screening all adults for obesity,[8] recognizing that health care providers have an important role in preventing, identifying and managing this chronic disease. The USPSTF also recommends that once a diagnosis of obesity has been established, physicians should offer or refer patients with a body mass index (BMI) ≥30 kg/m^2 to an intensive, interdisciplinary lifestyle intervention program.[8]

Despite these recommendations and formal recognition by the American Medical Association as a disease,[9] obesity continues to be underdiagnosed in clinical practice.[10] It is estimated that less than 30% of adults with obesity receive this diagnosis during their primary care physician (PCP) visit.[10] Furthermore, some data suggest that weight counseling as a component of primary healthcare services in the US has been declining significantly over the past decade.[11,12] Yet, obesity screening and recognition of obesity as a complex, chronic diagnosis are among the first steps leading to effective treatment[13]. Obesity-related electronic health records have been highlighted as a useful tool to assist health care providers in the screening and management of obesity.[14-17]

The primary objective of the present study was to determine the true prevalence of obesity and related comorbidities among patients being actively managed at the Cleveland Clinic using EHR data. A secondary goal was to evaluate how frequently a formal diagnosis of obesity, via ICD-9 coding, was documented among patients with a BMI ≥ 30 kg/m^2.

Methods

The enterprise-wide electronic health record (EHR) system at Cleveland Clinic was used to create a cross-sectional summary of actively-managed patients, stratified by BMI categories, as of July 1, 2015. All Cleveland Clinic facilities utilize the MyPractice EHR system, composed of an integrated suite of software modules created by Epic® Systems (Verona, WI), and which was first installed in 1998. The EHR includes patient demographics, social, medical, family and surgical history, vital signs, imaging data and pathology reports, and rich longitudinal clinical data (diagnosis, procedures, etc.) from both the inpatient and outpatient records. It contains discrete data linkage with Cleveland Clinic laboratory records, as well as detailed medication usage information. In 2014, Cleveland Clinic set a new annual record for outpatient visits (almost 6 million), and has >1 million active patients (2 or more encounters within the past 12 months).

Patients were included if they were ≥20 years of age on the index date (as they may not have reached their full height by 18 years of age). Patients were considered "actively managed" and included in the analysis if they had been seen by a PCP at least 3 times prior to the index date, with at least one of the visits having occurred within the immediate 18 months preceding the index date. Patients were excluded for any of the following reasons: median height <4'6" or >7'6"; weight >750 lbs (340 kg); pregnant or having recently given birth; amputees; diagnosis of HIV prior to the index date; diagnosis of hyperthyroidism, hypothyroidism, heart failure, radiation or chemotherapy treatment, or metastatic cancer between July 1st, 2013 and the index date (July 1st, 2015).

BMI calculations were determined using the most recent weight and median of all recorded heights obtained on or before the index date (July 1, 2015). The weight recorded closest to the index date was recorded as the study weight. Height and weight measures were obtained from outpatient encounters excluding ophthalmology, orthopedic, and psychiatry specialty visits because of a lack of precision of height and weight measurements obtained at these encounters. Income was defined as the five-year estimates (2008-2012) of median household income at the block group level obtained from the American Community Survey conducted by the U.S. Census Bureau.[18] The census block group was obtained by geocoding the patient address that was on file closest to baseline. BMI, weight, and smoking status were defined as the value recorded in the EHR closest to baseline (but without any time restrictions). Demographic and laboratory/vital sign data were recorded based on the most recent values available in the EHR on or before the index date. Comorbidities were identified in the EHR anytime up until the index date. Obesity diagnosis was based on ICD-9 code 278.0x and V-codes V85.3x and V85.4x.

Relationships between patient characteristics and weight classifications (BMI categories) were tested using univariate analysis, where chi-square was used for testing the association between the weight classifications and a categorical characteristic. The non-parametric Kruskal-Wallis test was used for continuous characteristics.

This study was approved by the Cleveland Clinic's Institutional Review Board.

Results

As of July 1st, 2015, a total of 324,199 active patients with a recorded BMI were identified to meet the inclusion/exclusion criteria (Figure 1). Of these, 255,775 (78.9%) patients met criteria for overweight or obesity according to their recorded BMI: 121,287 (37.4%) were found to be overweight, 75,199 (23.2%) had obesity class I (BMI 30-34.9), 34,152 (10.5%) had obesity class II (BMI 35-39.9) and 25,137 (7.8%) had obesity class III (BMI ≥40). The median time from July 1st, 2015 until the closest measurement of BMI was 4.7 months (interquartile range [IQR]: 1.9 to 13.2 months) for all 324,199 patients. The median time from July 1st, 2015 until the closest measurement of BMI for those with a BMI ≥ 25 (n = 255,775) and for BMI < 25 (68,424), was 4.4 months (IQR: 1.8, 9.4) and 6 months (IQR: 2.3, 11.9), respectively.

All measured associations between the weight classifications and the patient characteristics were statistically significant (P<0.0001).

Table 1. Study Population Characteristics

		Body Mass Index (kg/m^2)				
Variable	N (%) or Median (IQR)	<25[b]	25-29.9	30-34.9 (I)[c]	35-39.9 (II)[c]	≥40 (III)[c]
All Subjects	324,199 (100.0%)	68,424 (21.1%)	121,287 (37.4%)	75,199 (23.2%)	34,152 (10.5%)	25,137 (7.8%)
Age (years)[a]	52 (40, 63)	48 (32, 61)	54 (42, 65)	54 (43, 64)	52 (41, 62)	49 (38, 59)
Weight (lbs)[a]	185 (155, 218)	133 (120, 148)	177 (160, 194)	207 (188, 227)	234 (214, 257)	278 (250, 310)
Gender (n, column %; *row %*)						
Male	150,458 (46.4%)	20,340 (29.7%) *(13.5%)*	66,164 (54.6%) *(44.0%)*	40,092 (53.3%) *(26.6%)*	15,116 (44.3%) *(10.0%)*	8,746 (34.8%) *(5.8%)*
Female	173,736 (53.6%)	48,083 (70.3%) *(27.7%)*	55,121 (45.4%) *(31.2%)*	35,107 (46.7%) *(20.2%)*	19,034 (55.7%) *(11.0%)*	16,391 (65.2%) *(9.4%)*
Missing	5 (0.0%)					
Race (n, column %; *row %*)						
Caucasian (non-Hispanic)	251,028 (77.4%)	54,534 (81.4%) *(21.7%)*	95,779 (80.1%) *(38.2)*	57,548 (77.4%) *(22.9%)*	*25,392 (75.0%)* *(10.1%)*	17,775 (71.2%) *(7.1%)*
African American	41,789 (12.9%)	5,193 (7.7%) *(12.4%)*	13,253 (11.1%) *(31.7%)*	11,242 (15.1%) *(26.8%)*	6,264 (18.5%) *(15.0%)*	5,837 (23.4%) *(14.0%)*
Hispanic	11,799 (3.6%)	3,425 (5.1%) *(29.0%)*	4,586 (3.8%) *(38.9%)*	2387 (3.2%) *(20,1%)*	913 (2.7%) *(7.7%)*	488 (2.0%) *(4.1%)*
Asian/PI	4,670 (1.4%)	2,222 (3.3%) *(47.6%)*	1,759 (1.5%) *(37.7%)*	505 (0.7%) *(10.8%)*	130 (0.4%) *(2.8%)*	54 (0.2%) *(1.2%)*
Other	10,449 (3.2%)	1,661 (2.5%) *(15.9%)*	4,158 (3.5%) *(39.8%)*	2,663 (3.6%) *(25.5%)*	1,144 (3.4%) *(10.9%)*	823 (3.3%) *(7.9%)*
Missing	4,464 (1.4%)					
Smoking Status (n, column %; *row %*)						
Current	48,128 (14.8%)	11,295 (16.6%) *(23.5%)*	17,071 (14.1%) *(35.5%)*	11,019 (14.7%) *(22.9%)*	4,987 (14.6%) *(10.4%)*	3,756 (15.0%) *(7.8%)*
Former	96,633 (39.8%)	15,214 (22.3%) *(15.7%)*	37,899 (31.3%) *(39.2%)*	24,607 (32.8%) *(25.5%)*	11,094 (32.6%) *(11.5%)*	7,819 (31.2%) *(8.1%)*
Never	178,677 (55.1%)	41,707 (61.1%) *(23.3%)*	66,081 (54.6%) *(37.0%)*	39,404 (52.5%) *(22.1%)*	17,996 (52.8%) *(10.1%)*	13,489 (53.8%) *(7.5%)*

Missing	761 (0.2%)					
Median Household Income[a] (US$)	59,420 (43,640, 79,680)	62,210 (47,280, 82,120)	62,500 (45,440, 83,280)	58,300 (42,660, 77,790)	53,890 (39,710, 73,040)	49,940 (35,690, 66,320)
Missing (n,%)	4,319 (1.3%)					
ICD-9 Code for Obesity (%)[d]	76,777 (23.7%)	145b(0.2%)	12,576 (10.4%)	26,185 (34.8%)	18,934 (55.4%)	18,937 (75.3%)
278.0x ONLY	67,848 (88.4%)	136 (93.8%)	11,817 (94.0%)	21,477 (82.0%)	16,034 (84.7%)	18,384 (97.1%)
V85.3x or V85.4x	3,519 (4.6%)	7 (4.8%)	381 (3.0%)	2,162 (8.3%)	878 (2.5%)	91 (0.5%)
278.0x & V85.3x or V85.4x	5,410 (7.0%)	2 (1.4%)	378 (3.0%)	2,546 (9.7%)	2,022 (10.7%)	462 (2.4%)

[a] Median (interquartile range)

[b] 0.2% of subjects had ICD-9 codes for obesity for a median of 2.6 years prior to July 1, 2015

[c] Obesity Class

[d] ICD-9 codes indicating obesity diagnosis

V85 codes indicate the extent of obesity; i.e., V85.3x = BMI 30-39.9, V85.4x = BMI ≥ 40

All measured associations between the weight classifications and the patient characteristics were statistically significant with a P-value <0.0001

IQR, interquartile range; PI, Pacific Islander

Study Population

Table 1 provides study population characteristics and demographics. The median (IQR) age for the entire population was 52 years (40, 63) and the slight majority of patients were female (54%). The population included Caucasians (77.4%), African-Americans (12.9%), Hispanics (3.6%) and Asian/Pacific Islanders (1.4%).

Based on height and weight measurements, 78.9% of the patients had BMI values classified as overweight or obesity. For obesity class I (BMI 30-34.9), a higher percentage were males (53%), unlike patients with BMI <25 (30%) or obesity class II and III (44% and 35%, respectively). There was a significantly smaller percentage of males than females within the obesity class III category (35% males vs. 65% females, respectively).

The proportion of African-American individuals in increased as BMIcategory increased, while this pattern was not observed for other races.

The prevalence of smoking was similar among the various BMI categories compared to individuals with normal BMI.

As BMI category increased, median household income decreased, as determined by census block group of residence. The median household income (in US $) stratified by BMI category was: $62,210 (BMI <25); $62,500 (BMI 25-29.9); $58,300 (BMI 30-34.9); $53,890 (BMI 35-39.9); and $49,940 (BMI ≥40).

Documentation of an ICD-9 Code for Obesity. Out of 134,488 patients with a BMI ≥30, 48% (n=64,056) had a documented ICD-9 code for a diagnosis of obesity (ICD-9: 278.0x, V85.3x, V85.4x). Among patients with a BMI ≥40 (n=25,137), 75% (n=18,937) had an ICD-9 code for a diagnosis of obesity. In all 3 obesity classes, only a minority had a V85.x code for obesity class.

Table 2. Comorbidities, Vital Statistics and Laboratory Measurements Among Patients, Stratified by BMI Category

Variable	N (%)[a] or Median (IQR)	Body Mass Index (kg/m^2) N (%)[a] or Median (IQR)				
		<25	25-29.9	30-34.9 (I)[c]	35-39.9 (II)[c]	≥40 (III)[c]
All Subjects (% within row)	324,199 (100.0%)	68,424 (21.1%)	121,287 (37.4%)	75,199 (23.2%)	34,152 (10.5%)	25,137 (7.8%)
Diabetes	49,346 (15.2%)	3,063 (4.5%)	15,196 (12.5%)	14,542 (19.3%)	8,779 (25.7%)	7,766 (30.9%)
Pre-Diabetes	33,130 (10.2%)	602 (0.9%)	12,886 (10.6%)	10,319 (13.7%)	5,087 (14.9%)	4,236 (16.9%)
Hypertension	138,874 (42.8%)	15,854 (23.2%)	49,460 (40.8%)	38,558 (51.3%)	19,435 (56.9%)	15,567 (61.9%)
SBP (mm Hg)[b]	124 (114, 135)	118 (108, 128)	124 (114, 134)	126 (118, 137)	128 (120, 138)	130 (120, 140)
Missing	156 (0.0%)					
DBP (mm Hg)[b]	77 (70, 83)	72 (66, 80)	77 (70, 82)	79 (71, 84)	80 (72, 85)	80 (72, 86)
Missing	158 (0.0%)					
LDL (mg/dL)[b]	104 (84, 126)	99 (80, 120)	106 (85, 128)	106 (85, 128)	105 (84, 127)	104 (84, 124)
Missing, n (%)	60,448 (18.6%)					
HDL (mg/dL)[b]	52 (42, 65)	65 (53, 79)	53 (44, 64)	48 (40, 58)	46 (38, 56)	45 (38, 55)
Missing	55,634 (17.2%)					
Triglycerides (mg/dL)[b]	99 (70, 144)	74 (56, 102)	97 (69, 139)	114 (80, 164)	119 (85, 169)	117 (84, 165)
Missing	56,398 (17.4%)					
Fasting blood glucose (mg/dL)[b, d]	93 (86, 103)	88 (82, 94)	97.5 (93, 101)	103.1 (95, 106)	107 (97, 111)	109.8 (97, 114)
Missing	177,139 (54.6%)					
Random blood glucose (mg/dL)[b]	92 (84, 103)	88 (81, 95)	92 (85, 101)	95 (86, 106)	96 (86, 111)	97 (86, 114)
Missing	54,907 (16.9%)					
Glomerular Filtration [e]	87.4 (73.5, 100.2)	92.0 (78.2, 105.1)	85.4 (72.1, 97.9)	85.4 (71.8, 98.0)	87.8 (73.2, 100.4)	91.5 (76.1, 104.6)
Missing	29,061 (9.0%)					
HbA1c (%)[b]	5.8 (5.5, 6.5)	5.6 (5.3, 5.9)	5.8 (5.5, 6.3)	5.9 (5.6, 6.6)	6.0 (5.6, 6.8)	6.0 (5.7, 6.9)
Missing	207,248 (63.9%)					

Cerebrovascular Disease	22,436 (6.9%)	4,120 (6.0%)	9,002 (7.4%)	5,465 (7.3%)	2,357 (6.9%)	1,492 (5.9%)
Coronary Artery Disease	17,026 (5.3%)	2,210 (3.2%)	6,912 (5.7%)	4,769 (6.3%)	1,946 (5.7%)	1,189 (4.7%)
Heart Failure[f]	5,500 (1.7%)	994 (1.5%)	1,801 (1.5%)	1,368 (1.8%)	741 (2.2%)	596 (2.4%)

DBP, diastolic blood pressure; HDL, high density lipoprotein; IQR, interquartile range; LDL, low density lipoprotein; SBP, systolic blood pressure

[a] Except for "All Subjects" row, percentages reflect % within column (BMI) category

[b] Median (interquartile range)

[c] Obesity class

[d] Determination of "fasting" blood glucose: serum blood glucose obtained at the same time of those who had recorded fasting hours

[e] Glomerular Filtration Rate calculated via CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration)

[f] Heart failure recorded prior to 7/1/2013

Diabetes included patients with ICD-9 codes for Type 1 or Type 2 Diabetes.

Pre-diabetes defined as having appropriate ICD-9 code within 2 years + 1 fasting glucose 100mg/dL-125mg/dL or at least 2 fasting glucose measurements of 100mg/dL-125mg/dL, or HbA1c 5.7%-6.4%

Peripheral vascular disease was not included because it is inconsistently defined and not well-documented in medical records.

All measured associations between the weight classifications and the patient characteristics were statistically significant with a P-value <0.0001

Comorbidities

Table 2 presents data on comorbidity patterns in the study population, stratified by BMI category. The proportion of patients with diabetes or pre-diabetes rose with increasing BMI category. The prevalence of T2D and prediabetes within BMI categories increased from 4.5% and 0.9%, respectively of the BMI < 25 category to 30.9% and 16.9%, respectively, in the BMI ≥40 category. The rate of accurate ICD-9 coding for obesity among patients with T2D and BMI ≥30 was 59.3% (18,436/31,087), notably higher than among patients without T2D and having a BMI ≥30 (44.1%; 45,620/103,401).

The proportions of patients with HTN was also observed to rise with increasing BMI category, and both median systolic and diastolic blood pressures (BP, mmHg) increased with escalating BMI category.

There was no clinically meaningful difference in the median levels of LDL cholesterol (mg/dL) among the different BMI categories. Median HDL cholesterol levels were observed to decline with increasing BMI category. Median triglyceride levels increased from 74 mg/dL in the BMI <25 category to 119 mg/dL in the BMI 35-39.9 category, then appeared to plateau.

Patients with BMI ≥25 had a slightly higher prevalence of coronary artery disease compared to individuals with BMI <25, but no clinically meaningful differences in the prevalence of heart failure were observed between the BMI categories. There were no significant differences in the prevalence of cerebrovascular disease or glomerular filtration rate [calculated via CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration)] among the different groups of patients with obesity compared to lean subjects.

Glycemic control. The median fasting blood glucose values in individuals classified as overweight and obese were higher compared with patients with BMI <25 (**Table 2**). Median HbA1c values and random blood glucose measures for patients with overweight and obesity were marginally higher than in patients with BMI <25.

Table 3. Hypertension and Hyperlipidemia Medication Usage Among Patients, Stratified by BMI category

	Total	Body Mass Index (kg/m^2)				
Variable	N (%)	<25	25-29.9	30-34.9	35-39.9	≥40
All Subjects	324,199 (100.0%)	68,424 (21.1%)	121,287 (37.4%)	75,199 (23.2%)	34,152 (10.5%)	25,137 (7.8%)
HTN Medication	120,993 (37.3%)	13,345 (19.5%)	43,014 (35.5%)	33,774 (44.9%)	17,219 (50.4%)	13,641 (54.3%)
Number of classes of HTN medications, median (IQR)	0 (0, 2)	0 (0, 0)	0 (0, 2)	0 (0, 2)	1 (0, 2)	1 (0, 2)
Cholesterol Lowering Medications	83,637 (25.8%)	8,288 (12.1%)	33,802 (27.9%)	23,982 (31.9%)	10,626 (31.1%)	6,939 (27.6%)
Statin + second drug (non-statin)*	8,915 (2.7%)	646 (0.9%)	3,586 (3.0%)	2,698 (3.6%)	1,264 (3.7%)	721 (2.9%)
Statin only	69,071 (21.3%)	6,921 (10.1%)	28,068 (23.1%)	19,696 (26.2%)	8,657 (25.3%)	5,729 (22.8%)
Non-statin drug only	5,651 (1.7%)	721 (1.1%)	2,148 (1.9%)	1,588 (1.8%)	705 (2.1%)	489 (2.1%)

*Non-statin cholesterol lowering medications included bile acid sequestrants, fibrates, and other dyslipidemia drugs that comprise a variety of different mechanisms of action

All measured associations between the weight classifications and the patient characteristics were statistically significant with a P-value <0.0001

HTN, hypertension; IQR, interquartile range

Medications. As shown in **Table 3**, HTN medication utilization rose with increasing BMI categories from 19.5% in the lowest BMI category (<25) to 54.3% in the highest BMI category (≥40). Also, 30.8% of patients with obesity (BMI >30) were using a medication to control their cholesterol, whereas only 12.1% of lean subjects (BMI <25) were taking lipid-lowering medications (all P<0.0001). Patients with obesity were also more likely to be using a second lipid-lowering medication in addition to a statin.

Discussion

In this robust analysis of EHR data from the Cleveland Clinic, BMI values for almost 80% of patients fell within categories of overweight (37.4%) or obesity (41.5%). Thus, only about one in five patients had a BMI that was not indicative of overweight or obesity. The prevalence of overweight/obesity in this population (78%) is somewhat higher than estimated recently for the general US population; just over two-thirds (69%) of adults were estimated to be overweight or obese in the US between 2009-2012.[19,20] This observation could be, in part, because the population seeking medical care at our institution may be sicker, whereas the number reported through National Center for Health Statistics is self-reported/survey based.

Data from the National Health and Nutrition Examination Survey[1] demonstrated that the prevalence of obesity was 36.5% among U.S. adults during 2011–2014. The prevalence of obesity was noted to be higher in women and among non-Hispanic black and Hispanics. Consistent with these data, we identified a higher percentage of females compared with males among obesity classes II and III in our patient population. Higher rates of obesity diagnosis in female patients have been theoretically attributed to more frequent healthcare utilization by women in general or sex bias on the part of providers.[21] However, the current study was based on objective BMI data, thus sex bias was clearly not a factor. While the percentage of female patients was slightly higher than that of male patients in the overall study population, the ratio of female to male subjects in the highest BMI categories was greater. We also identified a higher prevalence of African-Americans and a lower median household income within the higher BMI categories. While the median age appeared to be relatively constant across BMI categories, when BMI classifications were stratified by categorical age groupings (data not shown), higher rates of BMI > 25 and > 30 were observed with increasing age category.

Diabetes is another global health epidemic that is driven largely by rising obesity rates.[22] Excess body fat increases the risk for prediabetes; men and women with obesity, respectively, have a 7-fold and 12-fold higher risk for developing T2D.[23] In the current dataset, 15% of the entire study population had a diagnosis of T2D. This finding corroborates those of a recent report which estimated the prevalence of diabetes among U.S. adults in 2011-2102 to be 12-14%.[24] However, the prevalence of pre-diabetes in the current study population (10%) was markedly lower than reported previously (38%).[24] The Cleveland Clinic employs strict criteria for a diagnosis of pre-diabetes, which may partly explain the discrepancy. We also noticed that patients with higher BMI had higher prevalences of T2D and prediabetes compared to leaner subjects.

Patients with obesity and T2D often have an increased incidence of cardiovascular disease risk factors, such as hypertension and dyslipidemia,[25,26] which is not surprising given that both obesity and T2D are independent risk factors for cardiovascular disease.[25,27] In agreement with these observations, our study found higher prevalences of hypertension and dyslipidemia (per cholesterol-lowering medication utilization) among patients with obesity compared to leaner subjects. We also noted an increased prevalence of coronary artery disease and congestive heart failure in our patients with obesity compared to lean subjects.

The U.S. Preventive Task Force (USPSTF) recommends screening all adults for obesity[8], yet the U.S. healthcare system still faces challenges in this area. The continued lack of recognition of obesity as a disease and under-diagnosis by clinicians postpones the initiation of treatment and increases the risk of developing complications. Body weight is a modifiable risk factor, and weight loss of 5-10% has been shown to improve multiple health outcomes, including cardiovascular risk factors.[28] In patients with obesity and T2D, benefits of weight loss may include improvements in insulin sensitivity, sleep apnea, less depression, less urinary incontinence, reduced need of diabetes medications, improved quality of life, and even lower costs[28,29]. Significant weight loss has even been associated with remission of T2D.[30] Several reasons have been suggested as responsible for why providers are reluctant to include obesity in the list of diagnoses in patients with BMI >30. These include: perception by health care providers that obesity is not a disease, low expectations for patient success, lack of time or knowledge to provide appropriate advice regarding nutrition, societal stigma, concerns with denials of payment for services, and limited therapeutic tools to treat patients with obesity.[12,15,31,32]

Identifying obesity is the first step leading to optimal interdisciplinary intervention ideally involving lifestyle modifications relating to nutrition and physical activity, as well as medications where necessary

to reduce appetite. Optimal obesity-related EHR functions should help to carry out this important task. We took advantage of our institution's EHR functions to document what is probably the most relevant finding of our study. In addition to identifying BMI-defined obesity in more than 40% of our patients, we observed that only half of such patients received a formal diagnosis of obesity via ICD-9 coding (278.00). We did observe that among patients with BMI-defined obesity, the percentage of patients that received a formal obesity diagnosis via ICD-9 documentation was 15% higher among patients with a diagnosis of diabetes compared with those not having a diagnosis of diabetes. This highlights that patients with obesity-related comorbidities like diabetes may be more likely to receive a formal diagnosis of obesity. This observation may be, in part, because patients with diabetes are sicker and are seen more frequently, affording more opportunities for a formal diagnosis of obesity to occur. It is also reasonable to surmise that patients who are diagnosed as having obesity may be more likely to undergo additional evaluation for comorbid conditions like diabetes.

Several studies have demonstrated the usefulness of EHR functions for screening and treating obesity, specifically with regard to assessing BMI, diagnosing obesity, and facilitating obesity counseling and treatment services.[16,17,33] In compliance with meaningful use standards, EHRs are required to calculate BMI for all patients, as well as plot and display weight and BMI charts. Unfortunately, few EHRs support physician's obesity-related care and there is low level of obesity-related sophistication in EHRs as recently published.[33] It should be noted that, while BMI categorization is a clinically practical and generally useful means of identifying obesity, BMI is an indirect measure of body fat and has been shown to have high specificity but low sensitivity to identify adiposity.[34] In addition, BMI measurements do not factor in age-related changes in body composition such as increased body fat and decreased muscle mass.[35]

It is also concerning that rates of weight counseling in primary care have significantly declined despite increased rates of overweight and obesity.[11,12,15] Given that physicians' advice about health risk interventions has been shown to have positive effects on patient risk status, it is important that PCPs do not overlook this rapidly increasing health problem. However, it remains unclear whether an increased recognition of obesity as a disease across the spectrum of providers (including both PCPs and specialists), and appropriate documentation within the EHR of this condition, will translate into an earlier referral to an obesity specialist so appropriate obesity therapy could be initiated. Further investigation is ongoing to address this important issue, which hopefully will facilitate the initiation of obesity therapy in our patients who suffer this condition.

Certain limitations of the current study should be noted. First, it was a cross-sectional study, although it utilized one of the largest EHR data repositories in the world. Cross-sectional data can identify associations but are unable to determine causality. Further research will be needed to clarify true associations between obesity status and comorbid medical conditions, or whether appropriate obesity diagnosis is triggering a higher rate of intentional work-up for such comorbidities in these individuals compared with those not diagnosed with obesity. Second, the prevalence of overweight and obesity noted in our patient population was higher than those estimated in the general US population.[19,20] This circumstance might reflect some population bias because the dataset was limited to individuals seeking health care at the Cleveland Clinic. Thirdly, although the dataset included a very large number of active patients (324,199), they all are part of a single institution. Finally, diagnostic coding procedures are subject to error, although the sheer volume of the dataset should have minimized the potential influence of occasional coding inaccuracies.

Conclusions

The results of this report highlight the sobering reality of obesity prevalence and associated comorbidities in the US. Yet despite the high prevalence, underdiagnosis continues to be a significant problem. More than three-quarters of the study population had a BMI consistent with overweight or obesity, but less than half received a formal diagnosis of such via ICD-9 documentation. This cross-sectional analysis was designed to evaluate the scope of the problem, and in doing so, has raised additional questions worthy of pursuit. Further analysis and research will be needed to fully decipher the likely complex factors contributing to the medical under-recognition of obesity.

Underdiagnosis and failing to recognize obesity as a treatable, chronic disease with serious health consequences are important barriers to effective management. Over coming years, we anticipate continued improvements in the documentation of obesity due to increasing therapy coverage by insurance companies, existing reimbursement incentives through the Centers for Medicare and Medicaid Services, and the effective utilization of obesity-related EHR functions. We believe that including obesity in the chronic problem lists of patients with a BMI >30 may be helpful in prompting discussions related to weight-related issues in appropriate individuals. Physicians have a tremendous opportunity to positively impact the health and general well-being of their patients with obesity if they commit to proactive strategies for diagnosis and intervention.

Contributorship Statement: K.M.P researched and analyzed the data and helped write the manuscript. B.B. and J.B. were involved in the concept and study design, data acquisition, data analysis and interpretation, drafting of initial manuscript, review and revision of the final manuscript, and gave final

approval on the manuscript. T.M.H. and R.S.Z. contributed to the discussion and reviewed/edited the article. B.J.W. and A.D.M. researched and analyzed the data, designed the analysis, and contributed to the discussion. S.X.K. and W.W. were involved in concept and study design, data analysis and interpretation, review and revision, and gave final approval on the manuscript. K.M.C. researched and analyzed the data. A.M. extracted, researched, and analyzed the data. B.S. and M.W.K. were involved in concept and study design, data analysis and interpretation, drafting of the manuscript, review and revision of manuscript, and final approval. J.M.B. was involved in the concept and study design, drafting of the manuscript, and project management.

Competing Interests: K.M.P. reports receiving research funding from Novo Nordisk and Merck, receiving consulting fees from Novo Nordisk, and Merck, and receiving honoraria from Merck, AstraZeneca, Sanofi, and Novo Nordisk for speaking/educational activities within the past 12 months. R.S.Z. reports receiving research funding from Novo Nordisk and Merck, and receiving speaker honoraria from Merck, and received consulting fees from Novo Nordisk and Merck within the past 12 months. B.J.W., M.W.K., A.M., K.M.C, and J.M.B. report receiving research funding from Novo Nordisk and Merck within the past 12 months. A.D.M. received research support from the Merck Investigator Studies Program and the Agency for Healthcare Research and Quality K08 HS024128. J.B. and B.S. were employees at Novo Nordisk and owned company stock while the research was being conducted. T.M.H, S.X.K., and W.W. are employees of Novo Nordisk and own company stock. B.B. reports receiving consulting fees and research support from Novo Nordisk in the past 12 months.

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Figure Legend

Figure 1. STROBE flow diagram of study population

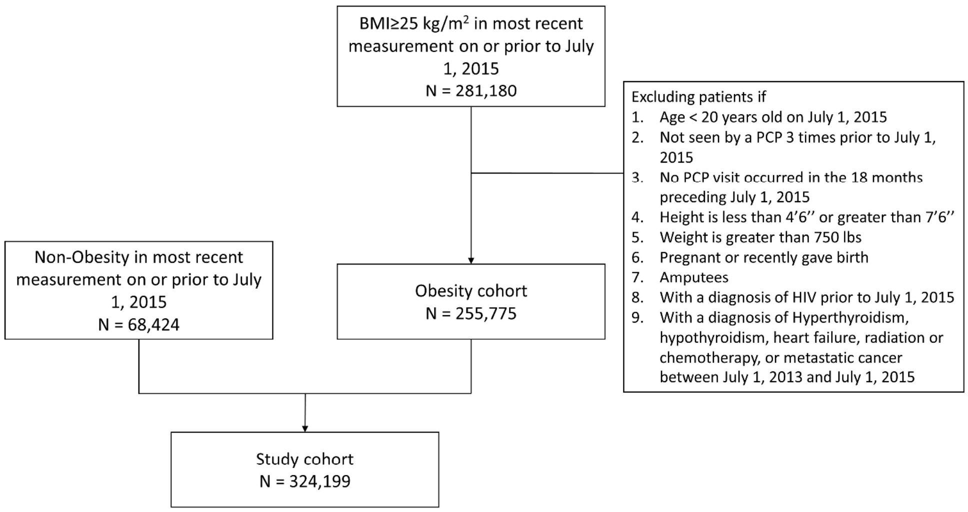

Figure 1

338x190mm (300 x 300 DPI)

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Prevalence and Recognition of Obesity and its Associated Comorbidities: Cross-Sectional Analysis of Electronic Health Record Data from a Large U.S. Integrated Health System

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Prevalence and Recognition of Obesity and its Associated Comorbidities: Cross-Sectional Analysis of Electronic Health Record Data from a Large U.S. Integrated Health System

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ABSTRACT

Objective: To determine the prevalence of obesity and its related comorbidities among patients being actively managed at a U.S. academic medical center, and to examine the frequency of a formal diagnosis of obesity, via ICD-9 documentation among patients with BMI $\geq$30 kg/m^2.

Design: The electronic health record system at Cleveland Clinic was used to create a cross-sectional summary of actively-managed patients meeting minimum primary care physician visit frequency requirements. Eligible patients were stratified by BMI categories, based on most recent weight and median of all recorded heights obtained on or before the index date of July 1, 2015. Relationships between patient characteristics and BMI categories were tested.

Setting: A large U.S. integrated health system

Results: A total of 324,199 active patients with a recorded BMI were identified. There were 121,287 (37.4%) patients found to have overweight (BMI ≥25 and < 29.9), 75,199 (23.2%) had BMI 30-34.9, 34,152 (10.5%) had BMI 35-39.9 and 25,137 (7.8%) had BMI ≥40. There was a higher prevalence of T2D, prediabetes, hypertension and cardiovascular disease (P-value <0.0001) within higher BMI compared to lower BMI categories. In patients with a BMI > 30 (N = 134,488), only 48% (64,056) had documentation of an obesity ICD-9 code. In those patients with a BMI > 40, only 75% had an obesity ICD-9 code.

Conclusions: This cross-sectional summary from a large U.S. integrated health system, found that 3 out of every 4 patients had overweight or obesity based on BMI. Patients within higher BMI categories had a higher prevalence of comorbidities. Less than half of patients who were identified as having obesity according to BMI received a formal diagnosis via ICD-9 documentation. The disease of obesity is very prevalent yet underdiagnosed in our clinics. The under diagnosing of obesity may serve as an important barrier to treatment initiation.

Article Summary

Strengths and Limitations of this study:

- The analysis included a very large sample of 324,199 patients with recorded BMI values.
- The electronic health records (EHR) used for the study (Cleveland Clinic) provide a rich source of demographic, clinical, laboratory, and prescription data on patients.
- Overweight and obesity categorizations were based on actual BMI calculations, not ICD coding.
- As a potential limitation, all patients were identified from a single institution's EHR, albeit one of the largest in the world (Cleveland Clinic).

- Another limitation is that all subjects were individuals seeking healthcare services, thus possibly not representative of the broader U.S. population.

Introduction

Obesity represents a major public health problem in the United States from the dual aspects of prevalence and consequence. The prevalence of obesity in the United States has nearly tripled over past decades, increasing from 13% in 1960–1962 to 36.5% during 2011–2014,[1] thus affecting an estimated 60 million American adults. Obesity is associated with a number of important chronic diseases such as type 2 diabetes (T2D), hypertension (HTN), dyslipidemia, coronary heart disease, stroke, several cancers, disability, and increased mortality.[2-7]

The U.S. Preventive Services Task Force (USPSTF) recommends screening all adults for obesity,[8] recognizing that health care providers have an important role in preventing, identifying and managing this chronic disease. The USPSTF also recommends that once a diagnosis of obesity has been established, physicians should offer or refer patients with a body mass index (BMI) $\geq$30 kg/m^2 to an intensive, interdisciplinary lifestyle intervention program.[8]

Despite these recommendations and formal recognition by the American Medical Association as a disease,[9] obesity continues to be underdiagnosed in clinical practice.[10] It is estimated that less than 30% of adults with obesity receive this diagnosis during their primary care physician (PCP) visit.[10] Furthermore, some data suggest that weight counseling as a component of primary healthcare services in the US has been declining significantly over the past decade.[11,12] Yet, obesity screening and recognition of obesity as a complex, chronic diagnosis are among the first steps leading to effective treatment[13]. Obesity-related electronic health records have been highlighted as a useful tool to assist health care providers in the screening and management of obesity.[14-17]

The primary objective of the present study was to determine the true prevalence of obesity and related comorbidities among patients being actively managed at the Cleveland Clinic using EHR data. A secondary goal was to evaluate how frequently a formal diagnosis of obesity, via ICD-9 coding, was documented among patients with a BMI $\geq$ 30 kg/m^2.

Methods

The enterprise-wide electronic health record (EHR) system at Cleveland Clinic was used to create a cross-sectional summary of actively-managed patients, stratified by BMI categories, as of July 1, 2015. All Cleveland Clinic facilities utilize the MyPractice EHR system, composed of an integrated suite of software modules created by Epic® Systems (Verona, WI), and which was first installed in 1998. The EHR includes patient demographics, social, medical, family and surgical history, vital signs, imaging data and pathology reports, and rich longitudinal clinical data (diagnosis, procedures, etc.) from both the inpatient and outpatient records. It contains discrete data linkage with Cleveland Clinic laboratory records, as well as detailed medication usage information. In 2014, Cleveland Clinic set a new annual record for outpatient visits (almost 6 million), and has >1 million active patients (2 or more encounters within the past 12 months).

Patients were included if they were ≥20 years of age on the index date (as they may not have reached their full height by 18 years of age). Patients were considered "actively managed" and included in the analysis if they had been seen by a PCP at least 3 times prior to the index date, with at least one of the visits having occurred within the immediate 18 months preceding the index date. Patients were excluded for any of the following reasons: median height <4'6" or >7'6"; weight >750 lbs (340 kg); pregnant or having recently given birth; amputees; diagnosis of HIV prior to the index date; diagnosis of hyperthyroidism, hypothyroidism, heart failure, radiation or chemotherapy treatment, or metastatic cancer between July 1st, 2013 and the index date (July 1st, 2015).

BMI calculations were determined using the most recent weight and median of all recorded heights obtained on or before the index date (July 1, 2015). The weight recorded closest to the index date was recorded as the study weight. Height and weight measures were obtained from outpatient encounters excluding ophthalmology, orthopedic, and psychiatry specialty visits because of a lack of precision of height and weight measurements obtained at these encounters. Income was defined as the five-year estimates (2008-2012) of median household income at the block group level obtained from the American Community Survey conducted by the U.S. Census Bureau.[18] The census block group was obtained by geocoding the patient address that was on file closest to baseline. BMI, weight, and smoking status were defined as the value recorded in the EHR closest to baseline (but without any time restrictions). Demographic and laboratory/vital sign data were recorded based on the most recent values available in the EHR on or before the index date. Comorbidities were identified in the EHR anytime up until the index date. Obesity diagnosis was based on ICD-9 code 278.0x and V-codes V85.3x and V85.4x.

Relationships between patient characteristics and weight classifications (BMI categories) were tested using univariate analysis, where chi-square was used for testing the association between the weight classifications and a categorical characteristic. The non-parametric Kruskal-Wallis test was used for continuous characteristics.

This study was approved by the Cleveland Clinic's Institutional Review Board.

Results

As of July 1st, 2015, a total of 324,199 active patients with a recorded BMI were identified to meet the inclusion/exclusion criteria (Figure 1). Of these, 255,775 (78.9%) patients met criteria for overweight or obesity according to their recorded BMI: 121,287 (37.4%) were found to be overweight, 75,199 (23.2%) had obesity class I (BMI 30-34.9), 34,152 (10.5%) had obesity class II (BMI 35-39.9) and 25,137 (7.8%) had obesity class III (BMI ≥40). The median time from July 1st, 2015 until the closest measurement of BMI was 4.7 months (interquartile range [IQR]: 1.9 to 13.2 months) for all 324,199 patients. The median time from July 1st, 2015 until the closest measurement of BMI for those with a BMI ≥ 25 (n = 255,775) and for BMI < 25 (68,424), was 4.4 months (IQR: 1.8, 9.4) and 6 months (IQR: 2.3, 11.9), respectively.

All measured associations between the weight classifications and the patient characteristics were statistically significant (P<0.0001).

Table 1. Study Population Characteristics

		Body Mass Index (kg/m^2)				
Variable	N (%) or Median (IQR)	<25[b]	25-29.9	30-34.9 (I)[c]	35-39.9 (II)[c]	≥40 (III)[c]
All Subjects	324,199 (100.0%)	68,424 (21.1%)	121,287 (37.4%)	75,199 (23.2%)	34,152 (10.5%)	25,137 (7.8%)
Age (years)[a]	52 (40, 63)	48 (32, 61)	54 (42, 65)	54 (43, 64)	52 (41, 62)	49 (38, 59)
Weight (lbs)[a]	185 (155, 218)	133 (120, 148)	177 (160, 194)	207 (188, 227)	234 (214, 257)	278 (250, 310)
Gender (n, column %; *row %*)						
Male	150,458 (46.4%)	20,340 (29.7%) *(13.5%)*	66,164 (54.6%) *(44.0%)*	40,092 (53.3%) *(26.6%)*	15,116 (44.3%) *(10.0%)*	8,746 (34.8%) *(5.8%)*
Female	173,736 (53.6%)	48,083 (70.3%) *(27.7%)*	55,121 (45.4%) *(31.2%)*	35,107 (46.7%) *(20.2%)*	19,034 (55.7%) *(11.0%)*	16,391 (65.2%) *(9.4%)*
Missing	5 (0.0%)					
Race (n, column %; *row %*)						
Caucasian (non-Hispanic)	251,028 (77.4%)	54,534 (81.4%) *(21.7%)*	95,779 (80.1%) *(38.2)*	57,548 (77.4%) *(22.9%)*	*25,392 (75.0%)* *(10.1%)*	17,775 (71.2%) *(7.1%)*
African American	41,789 (12.9%)	5,193 (7.7%) *(12.4%)*	13,253 (11.1%) *(31.7%)*	11,242 (15.1%) *(26.8%)*	6,264 (18.5%) *(15.0%)*	5,837 (23.4%) *(14.0%)*
Hispanic	11,799 (3.6%)	3,425 (5.1%) *(29.0%)*	4,586 (3.8%) *(38.9%)*	2387 (3.2%) *(20,1%)*	913 (2.7%) *(7.7%)*	488 (2.0%) *(4.1%)*
Asian/PI	4,670 (1.4%)	2,222 (3.3%) *(47.6%)*	1,759 (1.5%) *(37.7%)*	505 (0.7%) *(10.8%)*	130 (0.4%) *(2.8%)*	54 (0.2%) *(1.2%)*
Other	10,449 (3.2%)	1,661 (2.5%) *(15.9%)*	4,158 (3.5%) *(39.8%)*	2,663 (3.6%) *(25.5%)*	1,144 (3.4%) *(10.9%)*	823 (3.3%) *(7.9%)*
Missing	4,464 (1.4%)					
Smoking Status (n, column %; *row %*)						
Current	48,128 (14.8%)	11,295 (16.6%) *(23.5%)*	17,071 (14.1%) *(35.5%)*	11,019 (14.7%) *(22.9%)*	4,987 (14.6%) *(10.4%)*	3,756 (15.0%) *(7.8%)*
Former	96,633 (39.8%)	15,214 (22.3%) *(15.7%)*	37,899 (31.3%) *(39.2%)*	24,607 (32.8%) *(25.5%)*	11,094 (32.6%) *(11.5%)*	7,819 (31.2%) *(8.1%)*
Never	178,677 (55.1%)	41,707 (61.1%) *(23.3%)*	66,081 (54.6%) *(37.0%)*	39,404 (52.5%) *(22.1%)*	17,996 (52.8%) *(10.1%)*	13,489 (53.8%) *(7.5%)*

Missing	761 (0.2%)					
Median Household Income[a] (US$)	59,420 (43,640, 79,680)	62,210 (47,280, 82,120)	62,500 (45,440, 83,280)	58,300 (42,660, 77,790)	53,890 (39,710, 73,040)	49,940 (35,690, 66,320)
Missing (n,%)	4,319 (1.3%)					
ICD-9 Code for Obesity (%)[d]	76,777 (23.7%)	145b(0.2%)	12,576 (10.4%)	26,185 (34.8%)	18,934 (55.4%)	18,937 (75.3%)
278.0x ONLY	67,848 (88.4%)	136 (93.8%)	11,817 (94.0%)	21,477 (82.0%)	16,034 (84.7%)	18,384 (97.1%)
V85.3x or V85.4x	3,519 (4.6%)	7 (4.8%)	381 (3.0%)	2,162 (8.3%)	878 (2.5%)	91 (0.5%)
278.0x & V85.3x or V85.4x	5,410 (7.0%)	2 (1.4%)	378 (3.0%)	2,546 (9.7%)	2,022 (10.7%)	462 (2.4%)

[a] Median (interquartile range)

[b] 0.2% of subjects had ICD-9 codes for obesity for a median of 2.6 years prior to July 1, 2015

[c] Obesity Class

[d] ICD-9 codes indicating obesity diagnosis

V85 codes indicate the extent of obesity; i.e., V85.3x = BMI 30-39.9, V85.4x = BMI ≥ 40

All measured associations between the weight classifications and the patient characteristics were statistically significant with a P-value <0.0001

IQR, interquartile range; PI, Pacific Islander

Study Population

Table 1 provides study population characteristics and demographics. The median (IQR) age for the entire population was 52 years (40, 63) and the slight majority of patients were female (54%). The population included Caucasians (77.4%), African-Americans (12.9%), Hispanics (3.6%) and Asian/Pacific Islanders (1.4%).

Based on height and weight measurements, 78.9% of the patients had BMI values classified as overweight or obesity. For obesity class I (BMI 30-34.9), a higher percentage were males (53%), unlike patients with BMI <25 (30%) or obesity class II and III (44% and 35%, respectively). There was a significantly smaller percentage of males than females within the obesity class III category (35% males vs. 65% females, respectively).

The proportion of African-American individuals in increased as BMI category increased, while this pattern was not observed for other races.

The prevalence of smoking was similar among the various BMI categories compared to individuals with normal BMI.

As BMI category increased, median household income decreased, as determined by census block group of residence. The median household income (in US $) stratified by BMI category was: $62,210 (BMI <25); $62,500 (BMI 25-29.9); $58,300 (BMI 30-34.9); $53,890 (BMI 35-39.9); and $49,940 (BMI ≥40).

Documentation of an ICD-9 Code for Obesity. Out of 134,488 patients with a BMI ≥30, 48% (n=64,056) had a documented ICD-9 code for a diagnosis of obesity (ICD-9: 278.0x, V85.3x, V85.4x). Among patients with a BMI ≥40 (n=25,137), 75% (n=18,937) had an ICD-9 code for a diagnosis of obesity. In all 3 obesity classes, only a minority had a V85.x code for obesity class.

Table 2. Comorbidities, Vital Statistics and Laboratory Measurements Among Patients, Stratified by BMI Category

Variable	N (%)[a] or Median (IQR)	Body Mass Index (kg/m^2) N (%)[a] or Median (IQR)				
		<25	25-29.9	30-34.9 (I)[c]	35-39.9 (II)[c]	≥40 (III)[c]
All Subjects (% within row)	324,199 (100.0%)	68,424 (21.1%)	121,287 (37.4%)	75,199 (23.2%)	34,152 (10.5%)	25,137 (7.8%)
Diabetes	49,346 (15.2%)	3,063 (4.5%)	15,196 (12.5%)	14,542 (19.3%)	8,779 (25.7%)	7,766 (30.9%)
Pre-Diabetes	33,130 (10.2%)	602 (0.9%)	12,886 (10.6%)	10,319 (13.7%)	5,087 (14.9%)	4,236 (16.9%)
Hypertension	138,874 (42.8%)	15,854 (23.2%)	49,460 (40.8%)	38,558 (51.3%)	19,435 (56.9%)	15,567 (61.9%)
SBP (mm Hg)[b]	124 (114, 135)	118 (108, 128)	124 (114, 134)	126 (118, 137)	128 (120, 138)	130 (120, 140)
Missing	156 (0.0%)					
DBP (mm Hg)[b]	77 (70, 83)	72 (66, 80)	77 (70, 82)	79 (71, 84)	80 (72, 85)	80 (72, 86)
Missing	158 (0.0%)					
LDL (mg/dL)[b]	104 (84, 126)	99 (80, 120)	106 (85, 128)	106 (85, 128)	105 (84, 127)	104 (84, 124)
Missing, n (%)	60,448 (18.6%)					
HDL (mg/dL)[b]	52 (42, 65)	65 (53, 79)	53 (44, 64)	48 (40, 58)	46 (38, 56)	45 (38, 55)
Missing	55,634 (17.2%)					
Triglycerides (mg/dL)[b]	99 (70, 144)	74 (56, 102)	97 (69, 139)	114 (80, 164)	119 (85, 169)	117 (84, 165)
Missing	56,398 (17.4%)					
Fasting blood glucose (mg/dL)[b, d]	93 (86, 103)	88 (82, 94)	97.5 (93, 101)	103.1 (95, 106)	107 (97, 111)	109.8 (97, 114)
Missing	177,139 (54.6%)					
Random blood glucose (mg/dL)[b]	92 (84, 103)	88 (81, 95)	92 (85, 101)	95 (86, 106)	96 (86, 111)	97 (86, 114)
Missing	54,907 (16.9%)					
Glomerular Filtration [e]	87.4 (73.5, 100.2)	92.0 (78.2, 105.1)	85.4 (72.1, 97.9)	85.4 (71.8, 98.0)	87.8 (73.2, 100.4)	91.5 (76.1, 104.6)
Missing	29,061 (9.0%)					
HbA1c (%)[b]	5.8 (5.5, 6.5)	5.6 (5.3, 5.9)	5.8 (5.5, 6.3)	5.9 (5.6, 6.6)	6.0 (5.6, 6.8)	6.0 (5.7, 6.9)
Missing	207,248 (63.9%)					

Cerebrovascular Disease	22,436 (6.9%)	4,120 (6.0%)	9,002 (7.4%)	5,465 (7.3%)	2,357 (6.9%)	1,492 (5.9%)
Coronary Artery Disease	17,026 (5.3%)	2,210 (3.2%)	6,912 (5.7%)	4,769 (6.3%)	1,946 (5.7%)	1,189 (4.7%)
Heart Failure[f]	5,500 (1.7%)	994 (1.5%)	1,801 (1.5%)	1,368 (1.8%)	741 (2.2%)	596 (2.4%)

DBP, diastolic blood pressure; HDL, high density lipoprotein; IQR, interquartile range; LDL, low density lipoprotein; SBP, systolic blood pressure

[a] Except for "All Subjects" row, percentages reflect % within column (BMI) category

[b] Median (interquartile range)

[c] Obesity class

[d] Determination of "fasting" blood glucose: serum blood glucose obtained at the same time of those who had recorded fasting hours

[e] Glomerular Filtration Rate calculated via CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration)

[f] Heart failure recorded prior to 7/1/2013

Diabetes included patients with ICD-9 codes for Type 1 or Type 2 Diabetes.

Pre-diabetes defined as having appropriate ICD-9 code within 2 years + 1 fasting glucose 100mg/dL-125mg/dL or at least 2 fasting glucose measurements of 100mg/dL-125mg/dL, or HbA1c 5.7%-6.4%

Peripheral vascular disease was not included because it is inconsistently defined and not well-documented in medical records.

All measured associations between the weight classifications and the patient characteristics were statistically significant with a P-value <0.0001

Comorbidities

Table 2 presents data on comorbidity patterns in the study population, stratified by BMI category. The proportion of patients with diabetes or pre-diabetes rose with increasing BMI category. The prevalence of T2D and prediabetes within BMI categories increased from 4.5% and 0.9%, respectively of the BMI < 25 category to 30.9% and 16.9%, respectively, in the BMI ≥40 category. The rate of accurate ICD-9 coding for obesity among patients with T2D and BMI ≥30 was 59.3% (18,436/31,087), notably higher than among patients without T2D and having a BMI ≥30 (44.1%; 45,620/103,401).

The proportions of patients with HTN was also observed to rise with increasing BMI category, and both median systolic and diastolic blood pressures (BP, mmHg) increased with escalating BMI category.

There was no clinically meaningful difference in the median levels of LDL cholesterol (mg/dL) among the different BMI categories. Median HDL cholesterol levels were observed to decline with increasing BMI category. Median triglyceride levels increased from 74 mg/dL in the BMI <25 category to 119 mg/dL in the BMI 35-39.9 category, then appeared to plateau.

Patients with BMI ≥25 had a slightly higher prevalence of coronary artery disease compared to individuals with BMI <25, but no clinically meaningful differences in the prevalence of heart failure were observed between the BMI categories. There were no significant differences in the prevalence of cerebrovascular disease or glomerular filtration rate [calculated via CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration)] among the different groups of patients with obesity compared to lean subjects.

Glycemic control. The median fasting blood glucose values in individuals classified as overweight and obese were higher compared with patients with BMI <25 (**Table 2**). Median HbA1c values and random blood glucose measures for patients with overweight and obesity were marginally higher than in patients with BMI <25.

Table 3. Hypertension and Hyperlipidemia Medication Usage Among Patients, Stratified by BMI category

	Total	Body Mass Index (kg/m^2)				
Variable	N (%)	<25	25-29.9	30-34.9	35-39.9	≥40
All Subjects	324,199 (100.0%)	68,424 (21.1%)	121,287 (37.4%)	75,199 (23.2%)	34,152 (10.5%)	25,137 (7.8%)
HTN Medication	120,993 (37.3%)	13,345 (19.5%)	43,014 (35.5%)	33,774 (44.9%)	17,219 (50.4%)	13,641 (54.3%)
Number of classes of HTN medications, median (IQR)	0 (0, 2)	0 (0, 0)	0 (0, 2)	0 (0, 2)	1 (0, 2)	1 (0, 2)
Cholesterol Lowering Medications	83,637 (25.8%)	8,288 (12.1%)	33,802 (27.9%)	23,982 (31.9%)	10,626 (31.1%)	6,939 (27.6%)
Statin + second drug (non-statin)*	8,915 (2.7%)	646 (0.9%)	3,586 (3.0%)	2,698 (3.6%)	1,264 (3.7%)	721 (2.9%)
Statin only	69,071 (21.3%)	6,921 (10.1%)	28,068 (23.1%)	19,696 (26.2%)	8,657 (25.3%)	5,729 (22.8%)
Non-statin drug only	5,651 (1.7%)	721 (1.1%)	2,148 (1.9%)	1,588 (1.8%)	705 (2.1%)	489 (2.1%)

*Non-statin cholesterol lowering medications included bile acid sequestrants, fibrates, and other dyslipidemia drugs that comprise a variety of different mechanisms of action

All measured associations between the weight classifications and the patient characteristics were statistically significant with a P-value <0.0001

HTN, hypertension; IQR, interquartile range

Medications. As shown in **Table 3**, HTN medication utilization rose with increasing BMI categories from 19.5% in the lowest BMI category (<25) to 54.3% in the highest BMI category (≥40). Also, 30.8% of patients with obesity (BMI >30) were using a medication to control their cholesterol, whereas only 12.1% of lean subjects (BMI <25) were taking lipid-lowering medications (all P<0.0001). Patients with obesity were also more likely to be using a second lipid-lowering medication in addition to a statin.

Discussion

In this robust analysis of EHR data from the Cleveland Clinic, BMI values for almost 80% of patients fell within categories of overweight (37.4%) or obesity (41.5%). Thus, only about one in five patients had a BMI that was not indicative of overweight or obesity. The prevalence of overweight/obesity in this population (78%) is somewhat higher than estimated recently for the general US population; just over two-thirds (69%) of adults were estimated to be overweight or obese in the US between 2009-2012.[19,20] This observation could be, in part, because the population seeking medical care at our institution may be sicker, whereas the number reported through National Center for Health Statistics is self-reported/survey based.

Data from the National Health and Nutrition Examination Survey[1] demonstrated that the prevalence of obesity was 36.5% among U.S. adults during 2011–2014. The prevalence of obesity was noted to be higher in women and among non-Hispanic black and Hispanics. Consistent with these data, we identified a higher percentage of females compared with males among obesity classes II and III in our patient population. Higher rates of obesity diagnosis in female patients have been theoretically attributed to more frequent healthcare utilization by women in general or sex bias on the part of providers.[21] However, the current study was based on objective BMI data, thus sex bias was clearly not a factor. While the percentage of female patients was slightly higher than that of male patients in the overall study population, the ratio of female to male subjects in the highest BMI categories was greater. We also identified a higher prevalence of African-Americans and a lower median household income within the higher BMI categories. While the median age appeared to be relatively constant across BMI categories, when BMI classifications were stratified by categorical age groupings (data not shown), higher rates of BMI > 25 and > 30 were observed with increasing age category.

Diabetes is another global health epidemic that is driven largely by rising obesity rates.[22] Excess body fat increases the risk for prediabetes; men and women with obesity, respectively, have a 7-fold and 12-fold higher risk for developing T2D.[23] In the current dataset, 15% of the entire study population had a diagnosis of T2D. This finding corroborates those of a recent report which estimated the prevalence of diabetes among U.S. adults in 2011-2102 to be 12-14%.[24] However, the prevalence of pre-diabetes in the current study population (10%) was markedly lower than reported previously (38%).[24] The Cleveland Clinic employs strict criteria for a diagnosis of pre-diabetes, which may partly explain the discrepancy. We also noticed that patients with higher BMI had higher prevalences of T2D and prediabetes compared to leaner subjects.

Patients with obesity and T2D often have an increased incidence of cardiovascular disease risk factors, such as hypertension and dyslipidemia,[25,26] which is not surprising given that both obesity and T2D are independent risk factors for cardiovascular disease.[25,27] In agreement with these observations, our study found higher prevalences of hypertension and dyslipidemia (per cholesterol-lowering medication utilization) among patients with obesity compared to leaner subjects. We also noted an increased prevalence of coronary artery disease and congestive heart failure in our patients with obesity compared to lean subjects.

The U.S. Preventive Task Force (USPSTF) recommends screening all adults for obesity[8], yet the U.S. healthcare system still faces challenges in this area. The continued lack of recognition of obesity as a disease and under-diagnosis by clinicians postpones the initiation of treatment and increases the risk of developing complications. Body weight is a modifiable risk factor, and weight loss of 5-10% has been shown to improve multiple health outcomes, including cardiovascular risk factors.[28] In patients with obesity and T2D, benefits of weight loss may include improvements in insulin sensitivity, sleep apnea, less depression, less urinary incontinence, reduced need of diabetes medications, improved quality of life, and even lower costs[28,29]. Significant weight loss has even been associated with remission of T2D.[30] Several reasons have been suggested as responsible for why providers are reluctant to include obesity in the list of diagnoses in patients with BMI >30. These include: perception by health care providers that obesity is not a disease, low expectations for patient success, lack of time or knowledge to provide appropriate advice regarding nutrition, societal stigma, concerns with denials of payment for services, and limited therapeutic tools to treat patients with obesity.[12,15,31,32]

Identifying obesity is the first step leading to optimal interdisciplinary intervention ideally involving lifestyle modifications relating to nutrition and physical activity, as well as medications where necessary

to reduce appetite. Optimal obesity-related EHR functions should help to carry out this important task. We took advantage of our institution's EHR functions to document what is probably the most relevant finding of our study. In addition to identifying BMI-defined obesity in more than 40% of our patients, we observed that only half of such patients received a formal diagnosis of obesity via ICD-9 coding (278.00). We did observe that among patients with BMI-defined obesity, the percentage of patients that received a formal obesity diagnosis via ICD-9 documentation was 15% higher among patients with a diagnosis of diabetes compared with those not having a diagnosis of diabetes. This highlights that patients with obesity-related comorbidities like diabetes may be more likely to receive a formal diagnosis of obesity. This observation may be, in part, because patients with diabetes are sicker and are seen more frequently, affording more opportunities for a formal diagnosis of obesity to occur. It is also reasonable to surmise that patients who are diagnosed as having obesity may be more likely to undergo additional evaluation for comorbid conditions like diabetes.

Several studies have demonstrated the usefulness of EHR functions for screening and treating obesity, specifically with regard to assessing BMI, diagnosing obesity, and facilitating obesity counseling and treatment services.[16,17,33] In compliance with meaningful use standards, EHRs are required to calculate BMI for all patients, as well as plot and display weight and BMI charts. Unfortunately, few EHRs support physician's obesity-related care and there is low level of obesity-related sophistication in EHRs as recently published.[33] It should be noted that, while BMI categorization is a clinically practical and generally useful means of identifying obesity, BMI is an indirect measure of body fat and has been shown to have high specificity but low sensitivity to identify adiposity.[34] In addition, BMI measurements do not factor in age-related changes in body composition such as increased body fat and decreased muscle mass.[35]

It is also concerning that rates of weight counseling in primary care have significantly declined despite increased rates of overweight and obesity.[11,12,15] Given that physicians' advice about health risk interventions has been shown to have positive effects on patient risk status, it is important that PCPs do not overlook this rapidly increasing health problem. However, it remains unclear whether an increased recognition of obesity as a disease across the spectrum of providers (including both PCPs and specialists), and appropriate documentation within the EHR of this condition, will translate into an earlier referral to an obesity specialist so appropriate obesity therapy could be initiated. Further investigation is ongoing to address this important issue, which hopefully will facilitate the initiation of obesity therapy in our patients who suffer this condition.

Certain limitations of the current study should be noted. First, it was a cross-sectional study, although it utilized one of the largest EHR data repositories in the world. Cross-sectional data can identify associations but are unable to determine causality. Further research will be needed to clarify true associations between obesity status and comorbid medical conditions, or whether appropriate obesity diagnosis is triggering a higher rate of intentional work-up for such comorbidities in these individuals compared with those not diagnosed with obesity. Second, the prevalence of overweight and obesity noted in our patient population was higher than those estimated in the general US population.[19,20] This circumstance might reflect some population bias because the dataset was limited to individuals seeking health care at the Cleveland Clinic. Thirdly, although the dataset included a very large number of active patients (324,199), they all are part of a single institution, thus possibly limiting the generalizability of the findings. Finally, diagnostic coding procedures are subject to error, although the sheer volume of the dataset should have minimized the potential influence of occasional coding inaccuracies.

Conclusions

The results of this report highlight the sobering reality of obesity prevalence and associated comorbidities in the US. Yet despite the high prevalence, underdiagnosis continues to be a significant problem. More than three-quarters of the study population had a BMI consistent with overweight or obesity, but less than half received a formal diagnosis of such via ICD-9 documentation. This cross-sectional analysis was designed to evaluate the scope of the problem, and in doing so, has raised additional questions worthy of pursuit. Further analysis and research will be needed to fully decipher the likely complex factors contributing to the medical under-recognition of obesity.

Underdiagnosis and failing to recognize obesity as a treatable, chronic disease with serious health consequences are important barriers to effective management. Over coming years, we anticipate continued improvements in the documentation of obesity due to increasing therapy coverage by insurance companies, existing reimbursement incentives through the Centers for Medicare and Medicaid Services, and the effective utilization of obesity-related EHR functions. We believe that including obesity in the chronic problem lists of patients with a BMI >30 may be helpful in prompting discussions related to weight-related issues in appropriate individuals. Physicians have a tremendous opportunity to positively impact the health and general well-being of their patients with obesity if they commit to proactive strategies for diagnosis and intervention.

Contributorship Statement: K.M.P researched and analyzed the data and helped write the manuscript. B.B. and J.B. were involved in the concept and study design, data acquisition, data analysis and interpretation, drafting of initial manuscript, review and revision of the final manuscript, and gave final approval on the manuscript. T.M.H. and R.S.Z. contributed to the discussion and reviewed/edited the article. B.J.W. and A.D.M. researched and analyzed the data, designed the analysis, and contributed to the discussion. S.X.K. and W.W. were involved in concept and study design, data analysis and interpretation, review and revision, and gave final approval on the manuscript. K.M.C. researched and analyzed the data. A.M. extracted, researched, and analyzed the data. B.S. and M.W.K. were involved in concept and study design, data analysis and interpretation, drafting of the manuscript, review and revision of manuscript, and final approval. J.M.B. was involved in the concept and study design, drafting of the manuscript, and project management.

Competing Interests: K.M.P. reports receiving research funding from Novo Nordisk and Merck, receiving consulting fees from Novo Nordisk, and Merck, and receiving honoraria from Merck, AstraZeneca, Sanofi, and Novo Nordisk for speaking/educational activities within the past 12 months. R.S.Z. reports receiving research funding from Novo Nordisk and Merck, and receiving speaker honoraria from Merck, and received consulting fees from Novo Nordisk and Merck within the past 12 months. B.J.W., M.W.K., A.M., K.M.C, and J.M.B. report receiving research funding from Novo Nordisk and Merck within the past 12 months. A.D.M. received research support from the Merck Investigator Studies Program and the Agency for Healthcare Research and Quality K08 HS024128. J.B. and B.S. were employees at Novo Nordisk and owned company stock while the research was being conducted. T.M.H, S.X.K., and W.W. are employees of Novo Nordisk and own company stock. B.B. reports receiving consulting fees and research support from Novo Nordisk in the past 12 months.

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Data Sharing Statement: No additional data is available.

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Figure Legend

Figure 1. STROBE flow diagram of study population

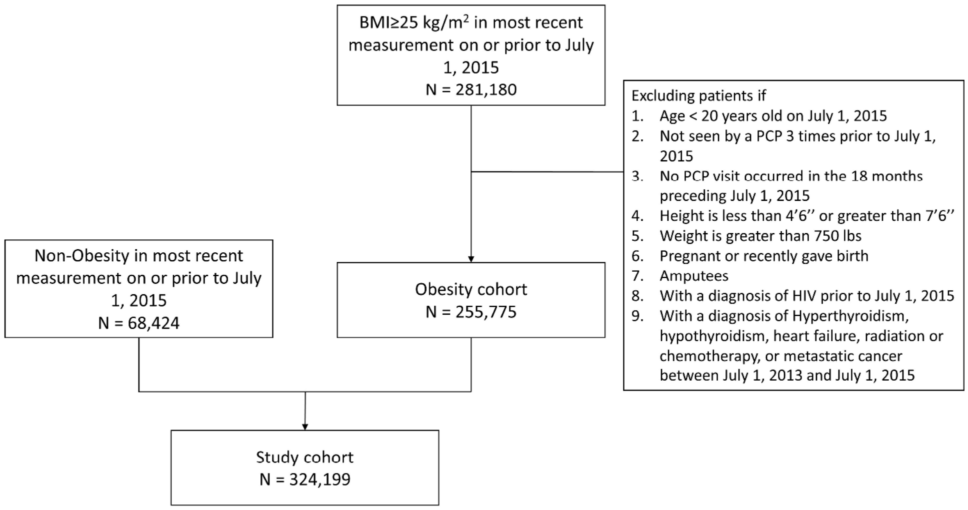

Figure 1

338x190mm (300 x 300 DPI)

bmjopen-2017-017583 (Pantalone et al)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1,2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	4[a]
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Fig. 1, p. 21
		(b) Give reasons for non-participation at each stage	Fig. 1, p. 21
		(c) Consider use of a flow diagram	Fig. 1, p. 21
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential	Table 1, pp. 6,7

	Item No	Recommendation	Page
		confounders	
		(b) Indicate number of participants with missing data for each variable of interest	Table 1, pp. 6,7
Outcome data	15*	Report numbers of outcome events or summary measures	Table 1, pp. 6,7; Table 2, p. 9; Table 3, p. 12 (and text, pp. 8.11.13)
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	NA
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

[a] Patients were excluded for certain characteristics that might uniquely or artificially skew BMI or body weight.