

Association of Body Mass Index with Chronic Conditions and Procedures in General Medicine Clinics at an Academic Health Center

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ABSTRACT

Objectives: Determine the prevalence of obesity in an adult patient population at an academic health center, and determine the association between body mass index (BMI) with type 2 diabetes, hypertension, coronary stent placement, joint replacement, and spinal fusion procedures stratified by age and sex.

Methods: Patient age, sex, BMI, and disease conditions/procedures for 51,435 adult patients seen since 2015 at either the family medicine clinic or general internal medicine clinic were obtained from the electronic health record using ICD-10 codes. A logistic regression analysis was performed with and without adjusting for the impact of age and sex. Odds ratios were calculated using both the adjusted and unadjusted models.

Results: The percentage of patients with a BMI in the healthy weight range, overweight range, and obesity categories was 28.5%, 31.3%, and 40.2%, respectively. The percent of adult patients with obesity steadily increased with age and peaked in the 49-54 age group at 49.5% for women and 46.9% for men, and then decreased with age. The odds ratios (both adjusted and unadjusted) indicated that individuals with greater BMI measurements are at significantly greater risk of type 2 diabetes (odds ratio 1.096), hypertension (odds ratio 1.097), coronary stent (odds ratio 1.051), and joint replacement (odds ratio 1.051), while no statistically significant relationship between spinal fusion and BMI was identified (odds ratio 1.014).

Conclusions: Our findings support the increasingly high prevalence of obesity in American society, the significant associations of obesity with chronic conditions and surgical/medical procedures, and the need for effective prevention and treatment interventions.

Keywords

Body mass index, Coronary stent, Diabetes, Hypertension, Joint replacement, Spinal fusion.

Introduction

Seventy to 75% of adult Americans are now overweight or obese, with the nation's adult population in 2017-2018 having an obesity rate of 42.5% [1]. Approximately 21 percent of children between 12-19 years of age are obese [2].

The health risks associated with being overweight have been well documented and include hypertension, diabetes and its

complications, liver disease, heart disease, sleep disturbance, some forms of cancer, and chronic joint disease [3]. It has also been shown that an extra 10 pounds of body weight add approximately 48,000 pounds of stress on the knee joint per mile walked [4]. Adults with diabetes are two to four times more likely to die from heart disease than adults without diabetes [5].

Obesity is one of the biggest drivers of preventable chronic diseases and health care costs in the U.S., with the total estimated cost of the obesity epidemic being \$210 billion per year, including the cost of absenteeism and reduced productivity [6]. Data from 1960 show that 13.4% of adult Americans were obese, compared

to 42.5% today [1]. The mean weight gain between 1960 and 2016 for adult men and women in the United States has been 32 pounds and 30 pounds, respectively [7,8]. A recent study projects that by 2030 nearly 1 in 2 adults will have obesity and nearly 1 in 4 adults will have severe obesity in the United States [9].

In order to determine the prevalence of obesity and its association with chronic conditions and procedures in a patient population of the family medicine and general internal medicine clinics of a large academic medical center, we pulled patient demographic and clinical data from the electronic medical record for over 50,000 adult patients who had been seen in the last 5 years. The primary objectives of the study were to determine the prevalence of obesity in this population and the association between body mass index (BMI) with type 2 diabetes, hypertension, coronary stent placement, joint replacement, and spinal fusion procedures stratified by age and sex. Institutional Review Board approval was obtained for this study.

Methods

Patient age, sex, BMI, and disease conditions/procedures for 51,435 adult patients (≥ 18 years old) seen in the last 5 years since 2015 at either the family medicine or general internal medicine clinic were obtained from the EPIC electronic health record using

ICD-10 codes. Univariate and multivariate logistic regression analyses were performed to assess the relationship between BMI and each outcome. Unadjusted and adjusted (controlling for age and sex) odds ratio point and interval estimates were obtained, along with significance p-values.

Categories of BMI were as follows: healthy weight 18.5-24.99, overweight 25.0-29.99, class 1 obesity 30.0-34.99, class 2 obesity 35.0-39.99, class 3 obesity ≥ 40.0 . Patients with a BMI > 90 or < 18.5 were excluded leaving 50,628 patients for analysis. Comparisons with p-values < 0.05 were considered significant.

Results

The percentage and number of patients with a BMI in the healthy weight range (28.5%), overweight range (31.3%), and obesity categories (40.2%) are shown in Table 1 stratified by age and sex. Additionally, Figure 1 shows the relationship between BMI and Age for each sex using BMI as a continuous variable. The percent of patients with obesity steadily increased with age and peaked in the 49-54 age group at 49.5% for women and 46.9% for men, and then decreased with age. The odds ratios (both adjusted and unadjusted) shown in Table 2 indicated that individuals with greater BMI measurements to be at significantly greater risk of type 2 diabetes (odds ratio 1.096), hypertension (odds ratio 1.097),

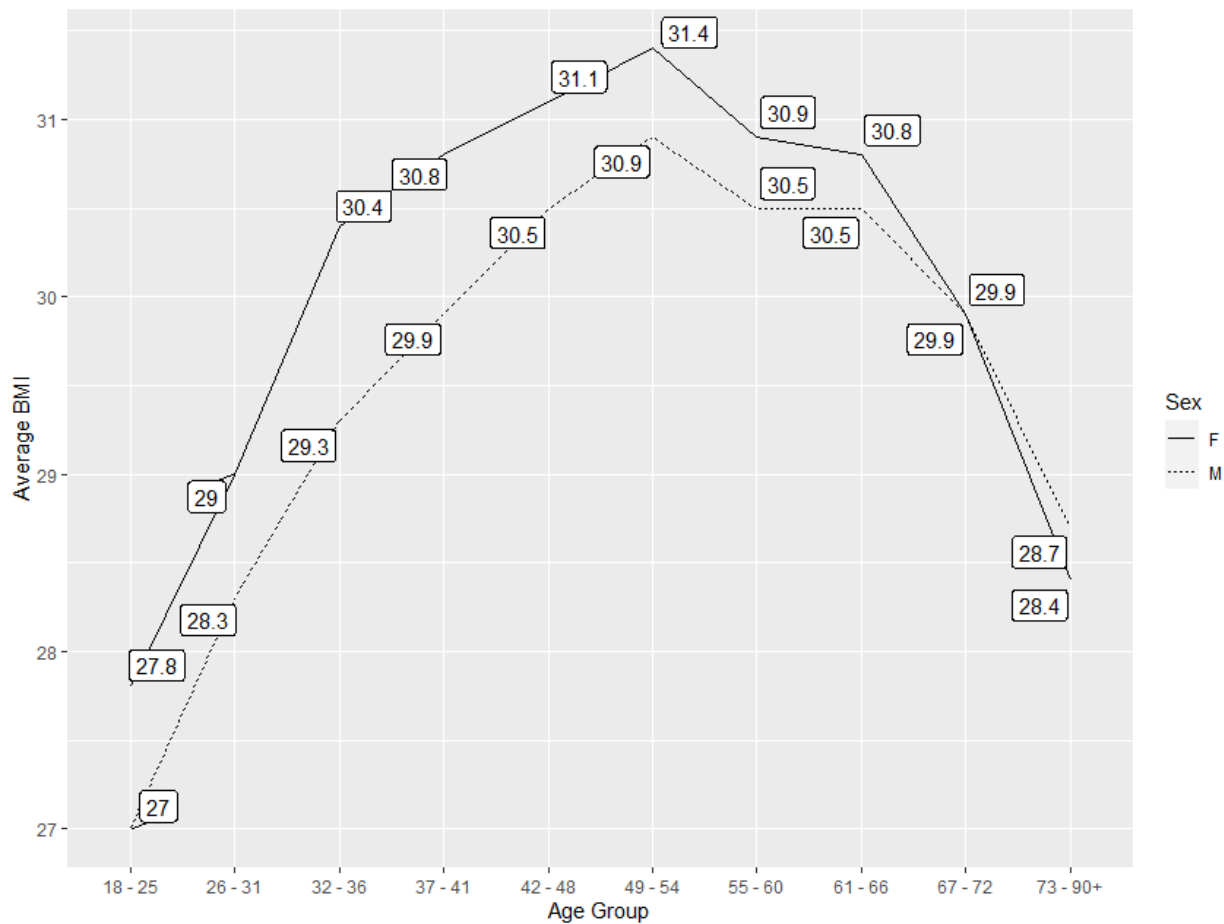


Figure 1: BMI Measurements and Age Group by Sex.

Table 1: Number and Percent in Each Weight Category by Age and Sex.

Age Group	Sex	Sample Size	Average BMI	Healthy	Overweight	Obese Class 1	Obese Class 2	Obese Class 3	Obese, Any Class
18 - 25	F	N = 2634	27.8	1198 (45.5%)	672 (25.5%)	355 (13.5%)	191 (7.3%)	218 (8.3%)	764 (29%)
26 - 31	F	N = 3449	29	1318 (38.2%)	909 (26.4%)	563 (16.3%)	318 (9.2%)	341 (9.9%)	1222 (35.4%)
32 - 36	F	N = 2642	30.4	866 (32.8%)	683 (25.9%)	447 (16.9%)	266 (10.1%)	380 (14.4%)	1093 (41.4%)
37 - 41	F	N = 2686	30.8	818 (30.5%)	680 (25.3%)	489 (18.2%)	328 (12.2%)	371 (13.8%)	1188 (44.2%)
42 - 48	F	N = 3035	31.1	836 (27.5%)	791 (26.1%)	584 (19.2%)	368 (12.1%)	456 (15%)	1408 (46.4%)
49 - 54	F	N = 2617	31.4	652 (24.9%)	669 (25.6%)	593 (22.7%)	317 (12.1%)	386 (14.7%)	1296 (49.5%)
55 - 60	F	N = 2890	30.9	797 (27.6%)	777 (26.9%)	574 (19.9%)	339 (11.7%)	403 (13.9%)	1316 (45.5%)
61 - 66	F	N = 2980	30.8	785 (26.3%)	822 (27.6%)	606 (20.3%)	381 (12.8%)	386 (13%)	1373 (46.1%)
67 - 72	F	N = 2667	29.9	787 (29.5%)	775 (29.1%)	510 (19.1%)	328 (12.3%)	267 (10%)	1105 (41.4%)
≥73	F	N = 3220	28.4	1061 (33%)	1090 (33.9%)	640 (19.9%)	280 (8.7%)	149 (4.6%)	1069 (33.2%)
18 - 25	M	N = 1487	27	658 (44.3%)	476 (32%)	200 (13.4%)	94 (6.3%)	59 (4%)	353 (23.7%)
26 - 31	M	N = 2440	28.3	848 (34.8%)	862 (35.3%)	392 (16.1%)	184 (7.5%)	154 (6.3%)	730 (29.9%)
32 - 36	M	N = 2095	29.3	574 (27.4%)	774 (36.9%)	423 (20.2%)	186 (8.9%)	138 (6.6%)	747 (35.7%)
37 - 41	M	N = 2022	29.9	481 (23.8%)	751 (37.1%)	423 (20.9%)	196 (9.7%)	171 (8.5%)	790 (39.1%)
42 - 48	M	N = 2511	30.5	469 (18.7%)	917 (36.5%)	626 (24.9%)	288 (11.5%)	211 (8.4%)	1125 (44.8%)
49 - 54	M	N = 2094	30.9	380 (18.1%)	734 (35.1%)	519 (24.8%)	263 (12.6%)	198 (9.5%)	980 (46.8%)
55 - 60	M	N = 2333	30.5	477 (20.4%)	803 (34.4%)	586 (25.1%)	264 (11.3%)	203 (8.7%)	1053 (45.1%)
61 - 66	M	N = 2334	30.5	424 (18.2%)	877 (37.6%)	563 (24.1%)	273 (11.7%)	197 (8.4%)	1033 (44.3%)
67 - 72	M	N = 2108	29.9	413 (19.6%)	822 (39%)	526 (25%)	215 (10.2%)	132 (6.3%)	873 (41.4%)
≥73	M	N = 2377	28.7	601 (25.3%)	946 (39.8%)	556 (23.4%)	192 (8.1%)	82 (3.4%)	830 (34.9%)

Table 2: BMI Odds Ratios on Outcomes of Interest.

Outcome	Proportion with Outcome	Unadjusted				Adjusted			
		BMI Odds Ratio	BMI OR 95% CI Lower	BMI OR 95% CI Upper	p-value	BMI Odds Ratio	BMI OR 95% CI Lower	BMI OR 95% CI Upper	p-value
Type 2 Diabetes	10.3%	1.078	1.075	1.082	<0.001	1.096	1.091	1.100	<0.001
Hypertension	31.3%	1.068	1.066	1.071	<0.001	1.097	1.093	1.100	<0.001
Coronary Stent	0.6%	1.032	1.018	1.045	<0.001	1.051	1.035	1.065	<0.001
Joint Replacement	2.3%	1.036	1.029	1.042	<0.001	1.051	1.043	1.058	<0.001
Spinal Fusion	0.7%	1.013	0.999	1.026	0.060	1.014	1.000	1.027	0.052

coronary stent (odds ratio 1.051), and joint replacement (odds ratio 1.051), while no statistically significant relationship between spinal fusion and BMI was identified (odds ratio 1.014). However, we did observe a significant ($p = 0.022$) difference in the proportion of patients receiving spinal fusion between the Class 2 and Class 3 obese patients.

Table 3 shows the percentage of patients with each clinical condition and/or procedure in each BMI category stratified by age category. The percentage of obese patients aged 18-25 years old with type 2 diabetes, hypertension, and joint replacement was 1.5%, 4.4%, and 0.3%, respectively, versus 0.2%, 1.0%, and 0.2% for the healthy weight group. The percentage of ≥ 73 year old patients in the obese weight group with type 2 diabetes, hypertension, and joint replacement was 29.1%, 79.4%, and 11.7%, respectively, versus 8.9%, 56.6%, and 5.1% for the healthy weight group. An increasing percentage of coronary stent and spinal fusion procedures with increasing BMI was only significant in the older age groups.

Conclusions

We found the prevalence of obesity to be over 40% in this patient population increasing significantly with age in both males and

females peaking in the 49-54 year old age group at almost 50% for men and women. Even in the 18-25 year old age group, 55.0% were overweight or obese. This high prevalence is consistent with that reported by the Centers for Disease Control and Prevention in the general population for this age group [8]. Whether the decrease in BMI after age 54 reflects an older generation who was thinner at earlier ages or a natural decrease in weight with loss of bone and muscle as one ages or a higher mortality rate in obese individuals at older ages is not clear. Nevertheless, the obesity rate has increased significantly since 1960 to 2018 from 13.4% to 42.5% [1].

As expected, we found the prevalence of diabetes type 2, hypertension, joint replacement and coronary stent procedures increases significantly with increasing BMI and age for men and women. Nearly 80% of obese patients ≥ 73 years old had hypertension, nearly 30% had type 2 diabetes, 12% had at least one joint replacement, and 2.5% had at least one coronary stent.

Spinal fusion procedures were not strongly associated with obesity whether using unadjusted or adjusted analyses. This result was unexpected given the higher prevalence of diabetes induced vascular disease and increased weight pressure on the spine. However, we did find a significant decrease in prevalence of spinal

Table 3: Percent with Disease/Procedure by Age Group and BMI Category.

BMI Category	Age Group	Sample Size	Diabetes Type 2%	Hypertension%	Coronary Stent%	Joint Replacement%	Spinal Fusion%
Healthy Weight	18 - 25	N = 1856	0.2%	1%	0%	0.2%	0.3%
Healthy Weight	26 - 31	N = 2166	0.2%	2%	0%	0.1%	0.3%
Healthy Weight	32 - 36	N = 1440	0.6%	3%	0%	0.1%	0.5%
Healthy Weight	37 - 41	N = 1299	1.1%	5.5%	0.1%	0.2%	0.2%
Healthy Weight	42 - 48	N = 1306	2.6%	9.3%	0%	0.5%	0.5%
Healthy Weight	49 - 54	N = 1032	4.6%	16.6%	0.2%	0.4%	0.2%
Healthy Weight	55 - 60	N = 1274	6.8%	24.6%	0.5%	1.3%	0.5%
Healthy Weight	61 - 66	N = 1209	5.5%	27.9%	0.6%	2.6%	1%
Healthy Weight	67 - 72	N = 1200	7%	36.8%	0.5%	3.1%	0.8%
Healthy Weight	≥73	N = 1662	8.9%	56.6%	1.2%	5.1%	1.2%
Overweight	18 - 25	N = 1148	0.3%	1.7%	0%	0.3%	0.1%
Overweight	26 - 31	N = 1772	0.3%	3.4%	0.1%	0.2%	0%
Overweight	32 - 36	N = 1458	0.9%	6.5%	0.1%	0.3%	0.1%
Overweight	37 - 41	N = 1431	2.2%	9.8%	0%	0.3%	0.1%
Overweight	42 - 48	N = 1708	5.4%	15.4%	0%	0.5%	0.7%
Overweight	49 - 54	N = 1403	7.8%	25.2%	0.4%	0.6%	0.9%
Overweight	55 - 60	N = 1580	10.6%	36.7%	0.6%	1.3%	1.1%
Overweight	61 - 66	N = 1699	11.7%	43.6%	0.7%	2.8%	1.1%
Overweight	67 - 72	N = 1597	13.8%	57.8%	1%	4.1%	0.9%
Overweight	≥73	N = 2036	17.2%	69.8%	1.8%	7.6%	1.4%
Obese Class 1	18 - 25	N = 555	0.7%	3.1%	0%	0.2%	0%
Obese Class 1	26 - 31	N = 956	1.9%	5.9%	0.1%	0.3%	0.1%
Obese Class 1	32 - 36	N = 870	3.7%	10.5%	0%	0.5%	0.1%
Obese Class 1	37 - 41	N = 912	4.9%	16.9%	0.1%	0.3%	0.3%
Obese Class 1	42 - 48	N = 1211	9.7%	26%	0.1%	0.8%	0.2%
Obese Class 1	49 - 54	N = 1112	13.1%	37.3%	0.5%	1.2%	1%
Obese Class 1	55 - 60	N = 1160	18.9%	50.2%	0.9%	2.1%	1%
Obese Class 1	61 - 66	N = 1169	19.1%	59.8%	1%	4.6%	1.3%
Obese Class 1	67 - 72	N = 1036	23%	64.7%	1.9%	6.7%	1.5%
Obese Class 1	≥73	N = 1196	27%	75.8%	2.7%	10.9%	1.3%
Obese Class 2	18 - 25	N = 285	1.4%	3.9%	0%	0.7%	0%
Obese Class 2	26 - 31	N = 503	3.2%	9.3%	0%	0%	0.4%
Obese Class 2	32 - 36	N = 452	5.5%	17.5%	0.2%	0.2%	0.2%
Obese Class 2	37 - 41	N = 524	8%	25%	0%	1%	0.6%
Obese Class 2	42 - 48	N = 656	14.2%	34.1%	0.3%	0.6%	1.1%
Obese Class 2	49 - 54	N = 581	22.5%	49.9%	0.7%	1.7%	0.9%
Obese Class 2	55 - 60	N = 603	25.7%	58.7%	0.7%	2.7%	1.8%
Obese Class 2	61 - 66	N = 654	32.9%	68%	0.8%	7.3%	0.6%
Obese Class 2	67 - 72	N = 543	36.5%	75.1%	2%	8.7%	2%
Obese Class 2	≥73	N = 472	28.4%	84.1%	1.9%	13.6%	2.3%
Obese Class 3	18 - 25	N = 277	3.2%	7.6%	0%	0%	0%
Obese Class 3	26 - 31	N = 495	7.3%	14.7%	0%	0.6%	0.2%
Obese Class 3	32 - 36	N = 518	9.1%	23.4%	0.2%	0.2%	0.2%
Obese Class 3	37 - 41	N = 542	14.6%	35.1%	0%	0.2%	0%
Obese Class 3	42 - 48	N = 667	22.2%	47.4%	0.3%	0.6%	0.4%
Obese Class 3	49 - 54	N = 584	26.5%	58.4%	1.4%	1.2%	0.9%
Obese Class 3	55 - 60	N = 606	35.1%	69.3%	1.2%	4%	1%
Obese Class 3	61 - 66	N = 583	37%	77.4%	1.4%	7%	1.4%
Obese Class 3	67 - 72	N = 399	41.4%	78.4%	1.8%	13%	0.8%
Obese Class 3	≥73	N = 231	41.1%	88.7%	2.6%	12.6%	1.3%
Obese, All Classes	18 - 25	N = 1117	1.5%	4.4%	0%	0.3%	0%
Obese, All Classes	26 - 31	N = 1954	3.6%	9%	0.1%	0.3%	0.2%
Obese, All Classes	32 - 36	N = 1840	5.7%	15.8%	0.1%	0.3%	0.2%
Obese, All Classes	37 - 41	N = 1978	8.4%	24%	0.1%	0.5%	0.3%
Obese, All Classes	42 - 48	N = 2534	14.2%	33.7%	0.2%	0.7%	0.5%
Obese, All Classes	49 - 54	N = 2277	19%	45.9%	0.8%	1.3%	0.9%
Obese, All Classes	55 - 60	N = 2369	24.8%	57.2%	0.9%	2.7%	1.2%
Obese, All Classes	61 - 66	N = 2406	27.2%	66.3%	1%	5.9%	1.1%
Obese, All Classes	67 - 72	N = 1978	30.4%	70.3%	1.9%	8.5%	1.5%
Obese, All Classes	≥73	N = 1899	29.1%	79.4%	2.5%	11.7%	1.6%

fusion procedures for patients with class 3 obesity versus class 2 obesity. This difference may be a result of deferring surgery in the class 3 obesity group due to a greater number of co-morbidities and hence greater risk of surgery.

Our findings confirm the significant associations between greater BMI and diabetes type 2, hypertension, joint replacement, and coronary heart disease, and just how prevalent these diseases are in at least a patient population in general medicine clinics at an academic health center.

In terms of how our findings compare with the prevalence found in the patient population of general medicine clinics, comparison data are hard to come by. However, the National Diabetes Statistics (NDS) report estimated that 13.0% of all adults in the United States have diabetes compared with 10.3% in our adult patient population, but the NDS report includes 2.8% with undiagnosed diabetes as well as type 1 diabetes so very close to our finding given that type 1 diabetes typically represents 5% of diabetes cases [10].

The National Health and Nutrition Examination Survey reported that 45.4% of the U.S adult population has hypertension compared with our finding of 31.3%, but this difference may reflect the younger patient population in our county which is overrepresented with young university students. [11].

Our finding that 4.4% of our patient population aged 50 and older had a joint replacement is less than the 6.6% the Mayo Clinic reported in their general population in Olmstead County in 2010 [12], but that difference may be due to the nature of patients in our general medicine clinics vs general population some of whom may have been seen only in orthopedic clinics.

In 2020 approximately 965,000 coronary angioplasties were performed in the United States mostly in adults for a rate of about 0.46% of the adult population [13]. Our prevalence of coronary stents of 0.6% in our adult patient population is similar, but higher because we included patient's most recent visit in the last 5 years.

The number of lumbar spinal fusions performed in adults per year in 2015 was 80 per 100,000 adults or 0.08% [14] and 72/100,000 for cervical spine surgery [15]. The percent of our adult patient population with a spinal fusion is 0.7% or a rate of 700 per 100,000 over potentially the last 5 years or 140 per 100,000 per year. Given our academic health system is a tertiary care center for complex procedures, our rates appear similar to the general population.

There are several limitations of our study. First, while the sample size of this study is large, a patient population at an academic health system likely has selection bias, with sicker and unhealthy patients being overrepresented compared to the general population. Second, not all patients may have been evaluated for these disorders and thereby underestimates the prevalence of these conditions. Third, some heights and weights to calculate BMI in the patient's chart may be based on self-report, as opposed to measurements, which may cause inaccurate BMI values.

Nevertheless, the sample size of over 50,000 patients, in family and general medicine clinics, likely reflects the patient populations of many academic health centers and what conditions can be expected among patients in different BMI categories by age and sex. This study also supports the public health concern of the increasing obesity in American society, and the need for effective prevention and treatment interventions.

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