Trends of Obesity Rates Between Patients Undergoing Primary Total Knee Arthroplasty and the General Population from 2013 to 2020

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Background: Obesity is a recognized risk factor for severe knee osteoarthritis. However, it remains unclear how obesity prevalence trends in the current population undergoing total knee arthroplasty (TKA) compare with those seen in individuals not undergoing this procedure. In this study, we assessed the yearly trends in body mass index (BMI) and obesity rates between patients who have undergone primary TKA and those in the general population.

Methods: We retrospectively reviewed all patients ≥18 years of age from January 2013 through December 2020 who underwent primary, elective TKA and those who had an annual routine physical examination at our institution within the same period. Baseline demographic characteristics were collected. The independent samples t test was used to compare means and the chi-square test was used to compare proportions between the 2 cohorts, and a linear regression was used to determine the significance of the yearly trends.

Results: A total of 11,333 patients who underwent primary TKA and 1,158,168 patients who underwent an annual physical examination were included in this study. After adjusting for age, we found the mean BMI for the TKA group to be significantly greater ($p < 0.001$) every year compared with the annual physicals group. The proportion of patients who were categorized into any obesity class (BMI, ≥30 kg/m^2), Class-I obesity (BMI, 30 to 34.9 kg/m^2), Class-II obesity (BMI, 35 to 39.9 kg/m^2), and Class-III obesity (BMI, ≥40 kg/m^2) was significantly higher for the TKA group each year compared with the annual physicals group. An analysis of trends over time showed a significantly increasing trend ($p < 0.001$) in BMI and obesity rates for the annual physicals group, but a stable trend for patients undergoing TKA.

Conclusions: Patients who underwent TKA continued to have higher BMI than the general population, which showed a steady increase over time. Physicians need to continue in their efforts to educate patients on weight management and healthy lifestyles to potentially delay the need for a surgical procedure.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

The rates of obesity have continued to rise in the United States[1]. The most recent data from the U.S. Centers for Disease Control and Prevention (CDC) showed that, from 1999 to 2018, the prevalence of obesity in the adult population has increased from 30.5% to 42.4%[2]. As obesity is a widely recognized risk factor for the development of severe knee osteoarthritis, this rise in prevalence is likely a contributory factor to the increasing demand for total knee arthroplasty (TKA) in the United States[3,4]. Obese patients (body mass index [BMI], ≥30 kg/m^2) are also at a higher risk for complications after TKA including wound complications, inpatient mortality, infection, venous thromboembolism, respiratory failure, stiffness, and revision arthroplasty[4-6].

To ascertain a broader understanding of the impact of obesity in the population undergoing TKA, investigators have analyzed changes in obesity prevalence from as early as 1998 to 2011 using national databases such as the Nationwide Inpatient Sample (NIS) and the National Hospital Discharge Survey and found increases in prevalence over time[1,7,8]. However, Fehring et al.[9] found that BMI not only increased significantly with time (1990 to 2005) in patients undergoing TKA but also was significantly higher when compared with the population of patients from their state.

Despite these reports, it remains largely unknown how the yearly trends of obesity in the current population undergoing TKA compare with the trends of obesity in the general population.

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By knowing this information, surgeons can better assess if patients undergoing TKA need additional counseling in weight management or optimization prior to the surgical procedure. Evaluating trends over time enables practitioners to better understand if there are any changes in discriminatory practices against obese patients who are otherwise candidates for TKA. Large academic centers may have robust programs for weight reduction that can be a model for smaller centers and practices around the country, so that obese patients have better access to optimizing their health in preparation for safe TKA.

Most studies, to our knowledge, have only assessed the changes in the prevalence of obesity for patients undergoing TKA in the early 2000s; there remains a paucity in the literature of more recent analyses of obesity trends in comparison with those seen in individuals not undergoing TKA. The purpose of this study was to assess the trends in BMI and obesity rates between patients who have undergone primary TKA at a large urban center and the overall population of patients at our institution within the last decade. Our ultimate goal is to inform surgeons of the recent trends in obesity so that they can guide patients undergoing TKA in making well-informed decisions with regard to their weight and lifestyle to maximize outcomes following TKA.

Materials and Methods

Study Design

We conducted a retrospective analysis of prospectively collected patient data from a single academic medical center and its affiliated tertiary orthopaedic specialty hospital. The study population was stratified into 2 cohorts: (1) those who underwent primary TKA at our institution from January 2013 to December 2020, and (2) all patients who had an annual routine physical examination within the same period. Annual physical examinations were identified using the Current Procedural Terminology (CPT) codes 99385, 99386, 99387, 99395, 99396, and 99397. Patients younger than the age of 18 years and those who underwent a nonelective surgical procedure, including revision TKA, were excluded from this analysis. Approval from our institutional review board was obtained prior to conducting this study.

Data Collection

The collected variables included baseline demographic characteristics such as age, sex, and BMI. All data were extracted using our institution's large electronic medical records database (Epic Caboodle, version 15) and were kept de-identified on encrypted Microsoft Excel software. The primary outcome compared the mean BMI and analyzed the yearly trends between patients undergoing primary TKA and those from the general population receiving routine physical examinations. We then separated the study population into 5 categories based on the CDC's classification of the various BMI subgroups[10]: underweight (BMI, <18.5 kg/m^2), all obese (BMI, ≥30 kg/m^2), Class-I obesity (BMI, 30 to 34.9 kg/m^2), Class-II obesity (BMI, 35 to 39.9 kg/m^2), and Class-III obesity (BMI, ≥40 kg/m^2). The secondary outcome compared the yearly trends in obesity rates between the 2 cohorts.

Statistical Analysis

All statistical analyses were performed using SPSS version 25 (IBM). Independent sample 2-sided t tests were utilized to detect statistical differences in continuous variables, and Pearson chi-square tests were used for categorical variables. Baseline characteristics such as age and sex were first compared using multilinear regressions to ensure that these factors were statistically equivalent between the 2 cohorts. Linear regression was used to calculate unstandardized the beta and 95% confidence interval (CI) for the difference in means for BMI. Linear regression with the Pearson correlation coefficient (r) was used to determine the significance of the yearly trends for both groups. A significant slope (Pearson r) indicated an increasing or decreasing trend, and a lack of significance indicated a stable trend.

Significance was set at $p < 0.05$ for all statistical measures used in this study.

Source of Funding

There was no external funding source for this study.

Results

A total of 11,333 patients undergoing primary TKA and 1,158,168 patients undergoing an annual physical examination were included in this study. A comparison of baseline characteristics between the 2 groups found significant age differences: patients in the annual physicals group were, on average, younger than the primary TKA group; the mean age (and standard deviation) was 43.94 ± 14.94 years in the annual physicals group and 65.53 ± 9.59 years in the primary TKA

TABLE I Patient Population Comparison (2013 to 2020)

	TKA Group (N = 11,333)	Annual Physicals Group (N = 1,158,168)	P Value
Age* *(yr)*	65.53 ± 9.59	43.94 ± 14.94	<0.001
Sex†			0.28
Female	7,703 (68.0%)	792,187 (68.4%)	
Male	3,630 (32.0%)	365,981 (31.6%)	

*The values are given as the mean and the standard deviation. †The values are given as the number of patients, with the percentage in parentheses.

TABLE II Trends of BMI: 2013 to 2020

	TKA Group		Annual Physicals Group			
Year	BMI*	Total No. of Patients	BMI*	Total No. of Patients	Unstandardized Beta†	P Value
2013	32.39 ± 6.82	616	25.40 ± 5.40	25,567	−4.76 (−5.20 to −4.32)	<0.001
2014	31.90 ± 6.77	959	25.66 ± 5.40	41,728	−4.12 (−4.47 to −3.76)	<0.001
2015	32.42 ± 6.74	1,416	26.27 ± 5.59	70,243	−4.35 (−4.65 to −4.06)	<0.001
2016	32.41 ± 6.54	1,540	26.59 ± 5.78	107,598	−4.24 (−4.53 to −3.95)	<0.001
2017	32.37 ± 6.34	1,702	26.94 ± 5.92	167,593	−4.03 (−4.31 to −3.75)	<0.001
2018	32.25 ± 6.30	1,832	27.36 ± 6.05	238,964	−3.59 (−3.87 to −3.31)	<0.001
2019	32.94 ± 6.09	1,839	27.47 ± 6.09	266,306	−4.27 (−4.55 to −3.99)	<0.001
2020	32.71 ± 6.52	1,429	27.66 ± 6.15	240,169	−4.03 (−4.35 to −3.71)	<0.001

*The values are given as the mean and the standard deviation in kilograms per meters squared. †The values are given as the unstandardized beta, with the 95% CI in parentheses, in kilograms per meters squared.

group ($p < 0.001$). However, no significant differences in sex were found (Table I). After adjusting for age, we found significant differences in the mean BMI between the 2 groups for each year. The mean BMI for the TKA group was significantly greater ($p < 0.001$) every year compared with the annual physicals group (Table II). Furthermore, a BMI trends analysis

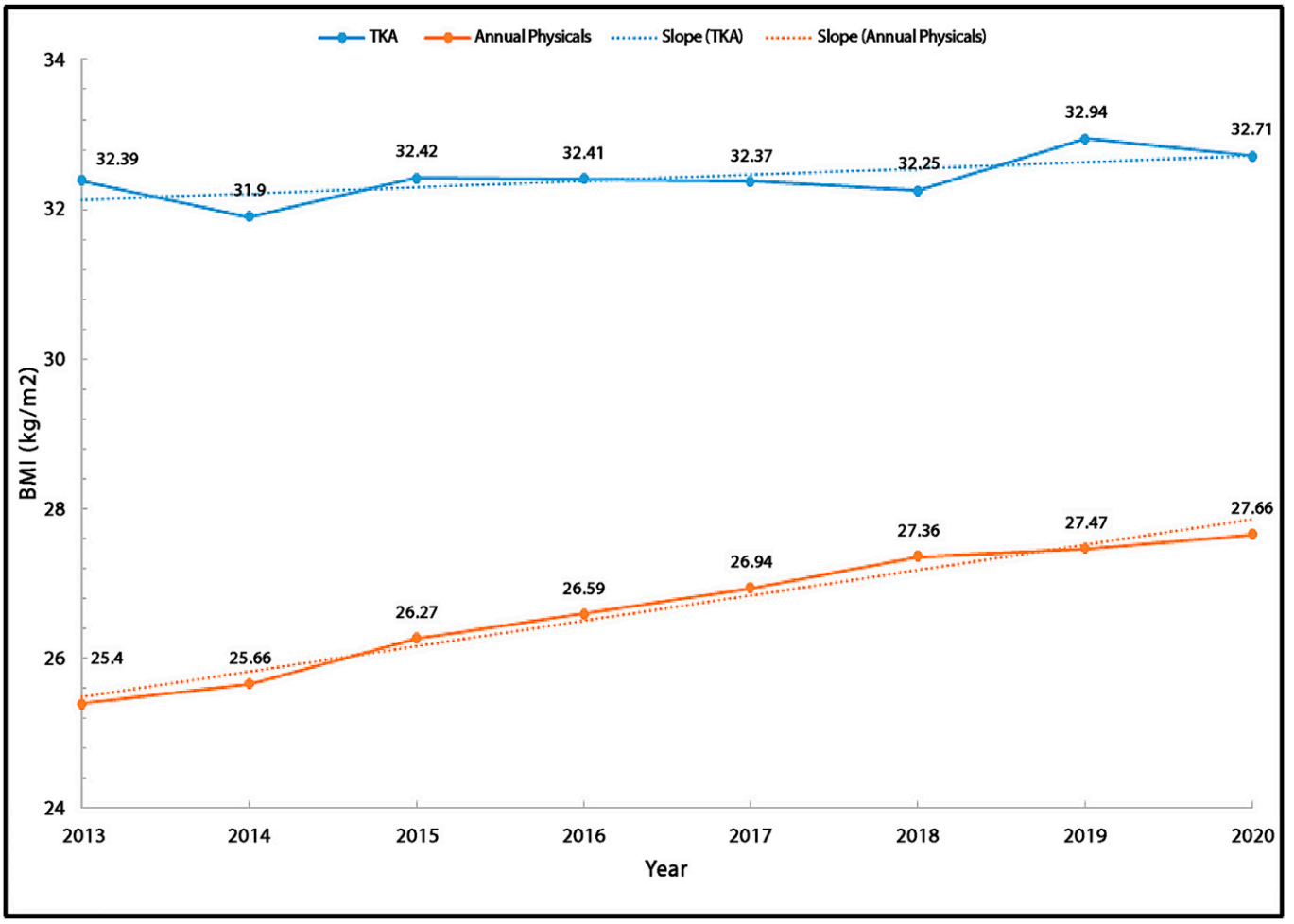

Fig. 1

Trends in BMI between the TKA group and the annual physicals group from 2013 to 2020.

TABLE III Significance of Slopes

	Slope*	P Value
Overall BMI trend		
TKA group	0.08 (−0.01 to 0.18)	0.077
Annual physicals group	0.34 (0.28 to 0.40)	<0.001
Underweight		
TKA group	−0.03 (−0.06 to 0.01)	0.101
Annual physicals group	−0.16 (−0.24 to −0.08)	0.003
Obese		
TKA group	0.65 (−0.003 to 1.30)	0.051
Annual physicals group	1.96 (1.63 to 2.28)	<0.001
Class-I obesity		
TKA group	0.02 (−0.54 to 0.58)	0.928
Annual physicals group	1.06 (0.86 to 1.27)	<0.001
Class-II obesity		
TKA group	0.78 (0.54 to 1.01)	<0.001
Annual physicals group	0.55 (0.47 to 0.64)	<0.001
Class-III obesity		
TKA group	−0.14 (−0.58 to 0.29)	0.446
Annual physicals group	0.33 (0.28 to 0.38)	<0.001

*The values are given as the Pearson r value, with the 95% CI in parentheses.

found a significant positive slope ($p < 0.001$) for the annual physicals group, indicating an increasing trend in BMI over time for the general population (Fig. 1, Table III). In contrast, the lack of significance found in the slope for the TKA group indicates a stable trend in BMI over time for patients undergoing TKA (Fig. 1, Table III).

After stratification into the 5 BMI categories, significant differences in the proportion of patients from each category were found between the 2 groups for each year ($p < 0.001$). The proportion of patients who were underweight in the primary TKA group was lower every year compared with the annual physicals group (Table IV). Conversely, the proportion of patients who were categorized into the remaining 4 subdivisions was significantly higher for the TKA group each year compared with the proportion seen in the annual physicals group (Table IV).

A trend analysis of obesity rates among the 5 categories showed significance ($p < 0.003$) in all slopes for the annual physicals group and in 1 slope for the TKA group (Table III). In the underweight category, a significant negative slope was found for the annual physicals group, but no significance was found in the slope for the TKA group, thus indicating a decreasing trend over time for the annual physicals group of underweight patients and a stable trend over time for patients undergoing TKA (Figs. 2 and 3). In the obese Class-I and Class-III subdivisions, significant positive slopes were found for the annual physicals group, but none were found for the TKA group, indicating increasing trends in obesity over time for the annual physicals group and stable trends over time for those undergoing TKA (Figs. 2 and 3). However, in the Class-II obesity subdivision, a significant positive slope was determined for both groups, indicating an increasing obesity trend over time for both the annual physicals group and those undergoing TKA (Figs. 2 and 3).

Discussion

As the obesity epidemic in the United States continues to rise, the risk of developing severe knee osteoarthritis increases, contributing to the growing demand for TKA[1-4]. Earlier reports of obesity trends among patients who underwent primary TKA have shown an increase in prevalence rates as time progresses[1,7,8]. One study published in 2007 showed higher BMI levels in patients undergoing TKA compared with the general population[9]. However, to our knowledge, the current literature lacks a recent analysis of obesity trends in the population undergoing TKA compared with the general adult population. We conducted a comparative analysis of BMI and obesity trends between patients who underwent primary TKA at our academic medical center from 2013 through 2020 and patients who had an annual routine physical examination within the same institution and time period. Our findings suggest that, although patients who underwent TKA were significantly more obese than the general adult population, there was a stable trend in BMI over time in these patients compared with a trend of increasing BMI in our general population.

BMI Trends

Although we found BMI to remain stable around 32 kg/m^2 in the TKA group, Fehring et al.[9] reported a significant increase ($p = 0.0005$) from 1990 to 2005 (29.9 to 32.6 kg/m^2), and Kremers et al.[11] reported an increase from 2000 to 2008 (approximately 30.3 to 31.7 kg/m^2). BMI levels in patients undergoing TKA seem to have plateaued after these early time periods. Goudie et al.[12] reported a mean BMI of 32.0 kg/m^2 from 2009 to 2012 at their institution, which is consistent with our findings from 2013 through 2020. One possible explanation for the change in BMI trends seen in the TKA population between 1990 to 2008 and 2009 to 2020 could be the increase in knowledge about the association of obesity and outcomes in TKA. Studies conducted between 2006 and 2009 have shown that morbid obesity, defined as BMI of ≥40 kg/m^2, can lead to lower quality of life and performance after TKA as well as a higher risk of postoperative infections and other perioperative complications[13-16].

In contrast to our TKA group, our analysis of patients in the annual physicals group showed mean BMI to increase significantly from 25.40 ± 5.40 kg/m^2 in 2013 to 27.66 ± 6.15 kg/m^2 in 2020. Thus, these patients are becoming more overweight (BMI, 25 to 30 kg/m^2), but the average patient has not crossed the obesity threshold. Given that patients undergoing TKA have generally been obese, with a mean BMI of 32.0 kg/m^2, from 2009 onwards, it is not surprising to find that they had significantly higher BMI levels every year than those in the annual physicals group. Additionally, there seems to have been an annual increase in the number of patients undergoing TKA and those undergoing an annual physical examination, which can be explained by the constantly aging population and

TABLE IV Proportion of Patients in Each Category*

BMI Category	Patients in BMI Category†	
	TKA Group	Annual Physicals Group
Underweight (BMI, <18.5 kg/m²)		
2013	2 (0.3%)	778 (3.0%)
2014	2 (0.2%)	1,178 (2.8%)
2015	5 (0.4%)	1,536 (2.2%)
2016	3 (0.2%)	2,311 (2.1%)
2017	4 (0.2%)	3,547 (2.1%)
2018	5 (0.3%)	4,289 (1.8%)
2019	2 (0.1%)	4,956 (1.9%)
2020	1 (0.1%)	4,545 (1.9%)
Obese (BMI, ≥30 kg/m²)		
2013	373 (60.6%)	4,178 (16.3%)
2014	545 (56.8%)	7,354 (17.6%)
2015	836 (59.0%)	14,617 (20.8%)
2016	921 (59.8%)	24,602 (22.9%)
2017	1,049 (61.6%)	42,183 (25.2%)
2018	1,112 (60.7%)	65,625 (27.5%)
2019	1,186 (64.5%)	74,304 (27.9%)
2020	884 (61.9%)	70,004 (29.2%)
Class-I obesity (BMI, 30 to 34.9 kg/m²)		
2013	190 (30.8%)	2,682 (10.5%)
2014	266 (27.7%)	4,774 (11.4%)
2015	396 (28.0%)	9,283 (13.2%)
2016	439 (28.5%)	15,455 (14.4%)
2017	521 (30.6%)	26,094 (15.6%)
2018	558 (30.5%)	40,062 (16.8%)
2019	556 (30.2%)	45,076 (16.9%)
2020	399 (27.9%)	42,243 (17.6%)
Class-II obesity (BMI, 35 to 39.9 kg/m²)		
2013	93 (15.1%)	937 (3.7%)
2014	167 (17.4%)	1,675 (4.0%)
2015	244 (17.2%)	3,467 (4.9%)
2016	277 (18.0%)	5,935 (5.5%)
2017	321 (18.9%)	10,281 (6.1%)
2018	341 (18.6%)	16,307 (6.8%)
2019	374 (20.3%)	18,541 (7.0%)
2020	308 (21.6%)	17,548 (7.3%)
Class-III obesity (BMI, ≥40 kg/m²)		
2013	90 (14.6%)	559 (2.2%)
2014	112 (11.7%)	905 (2.2%)
2015	196 (13.8%)	1,867 (2.7%)
2016	205 (13.3%)	3,212 (3.0%)
2017	207 (12.2%)	5,808 (3.5%)
2018	213 (11.6%)	9,256 (3.9%)
2019	256 (13.9%)	10,687 (4.0%)
2020	177 (12.4%)	10,249 (4.3%)

*The p values between the groups were p < 0.001 for all. †The values are given as the number of patients, with the percentage, based on the total number in each group, in parentheses.

the increase of adverse risk factors such as obesity and osteoarthritis[17-19] as well as the population increasing as a whole in the region. Furthermore, with TKA becoming increasingly effective in treating advanced osteoarthritis, the demand for TKA is rising annually[18].

Obesity Trends: The Underweight Category

In the first of the 5 different BMI categories, we found that the proportion of patients who were underweight remained stable (approximately 0.2%) over time in the TKA group but significantly decreased (3.0% to 1.9%) in the annual physicals group. Kremers et al.[11] reported a similar trend for patients undergoing TKA, in which the proportion of underweight patients remained <1% from 2000 to 2008. Furthermore, the data provided by the National Health and Nutrition Examination Survey (NHANES) showed that the prevalence of underweight status among U.S. adults decreased from 2.0% in 1990 to 1.5% in 2016[20]. Our findings with regard to the underweight category in both cohorts from 2013 to 2020 seem to be consistent with previously reported trends.

Obesity Trends: All-Class Obesity (BMI ≥30 kg/m²), Class I, and Class III

We found the mean rates of obesity in the TKA group to be 60.6% for all obesity classes (BMI, ≥30 kg/m²), 29.3% for the subgroup of Class I, and 12.9% for the subgroup of Class III. Three single-institution studies on patients undergoing TKA were consistent with our all-class obesity findings, with reported rates of 60% in 2005, 59% in 2008, and 61.4% from 2009 to 2012[9,11,12]. Goudie et al.[12] reported prevalence rates of approximately 30% for Class-I obesity and 10% for Class-III obesity from 2009 to 2012, further supporting our results. However, most studies looking at earlier time points have shown increasing trends. Fehring et al.[9] reported institutional increases of all-class obesity rates (42% to 60%) and of Class-III obesity rates (10.5% to 17.1%) from 1990 to 2005. Kremers et al.[11] also reported institutional increases of all-class obesity rates (49% to 59%) and Class-III obesity rates (22% to 32%) from 2000 to 2008. This observed change in obesity trends seen in the population undergoing TKA from 1990 to 2012 and 2013 to 2020 follows a similar pattern of changes seen in the BMI trends.

In our annual physicals cohort, we found significant increases in rates of all-class obesity (16.3% to 29.2%), Class-I obesity (10.5%

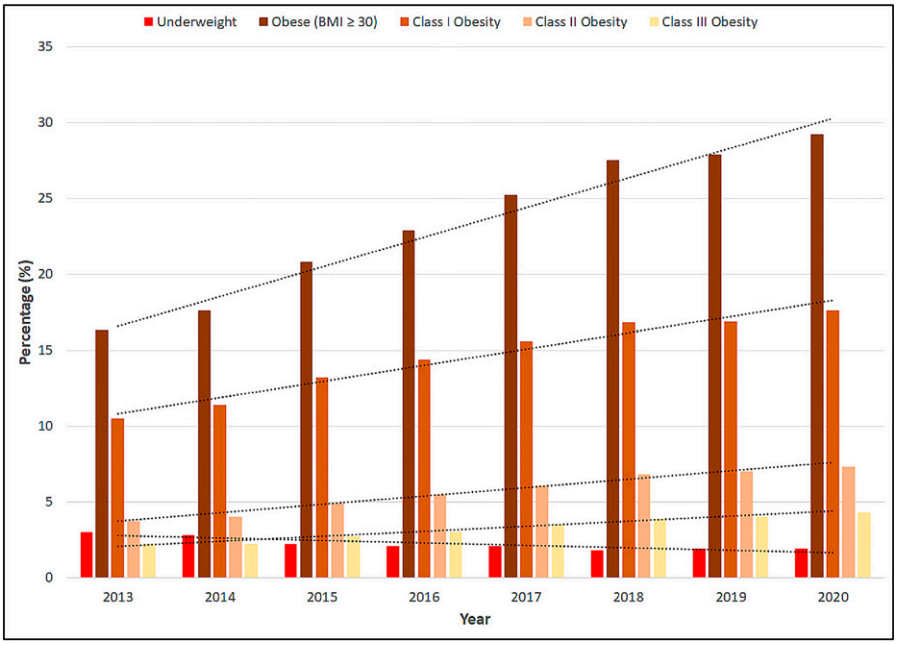

Fig. 2

Trends in obesity rates of patients undergoing annual physicals among 5 categories from 2013 to 2020.

to 17.6%), and Class-III obesity (2.2% to 4.3%). The CDC also reported significant increases nationally but with larger rates; from 1999 to 2000 through 2017 to 2018, the age-adjusted national prevalence increased from 30.5% to 42.4% for all-class obesity and from 4.7% to 9.2% for Class-III obesity[2]. After comparing our results with those observed in both the state and city of New York, we found the rates and trends to be more similar than those of the national prevalence. The age-standardized prevalence of obesity in the New York City adult population increased significantly from 2004 to 2013 and 2014, from 27.5% to 32.5% ($p = 0.01$)[21], and the prevalence in New York State from 1997 to 2018 increased from 16% to 27.6%[22]. Consistent with our results for the BMI trends, patients in the TKA group, on average, were significantly more obese every year than the patients in the annual physicals group.

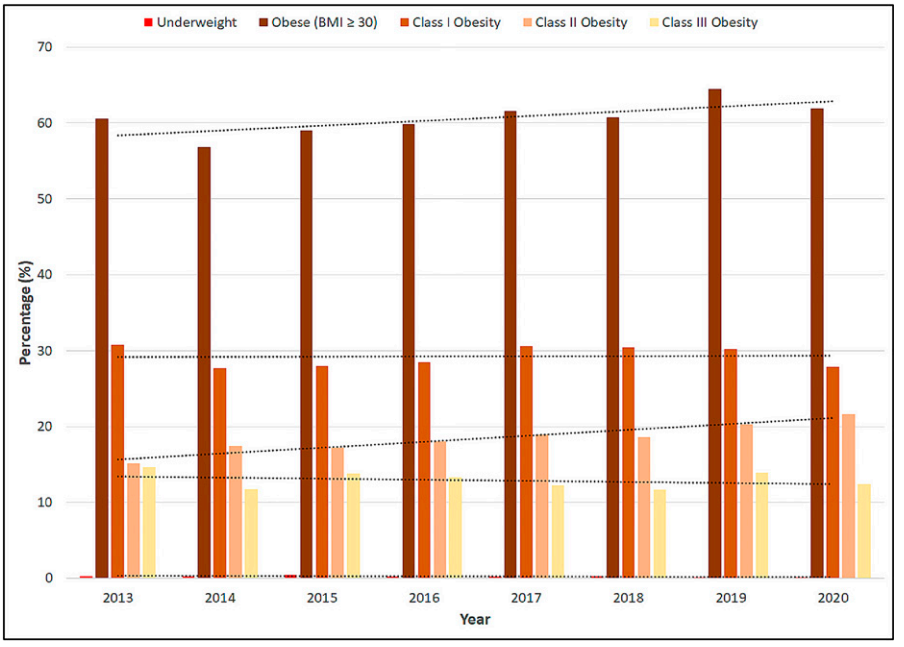

Fig. 3

Trends in obesity rates of patients undergoing TKA among 5 categories from 2013 to 2020.

Limitations

Our study had limitations, some of which are inherent in a retrospective review. For example, specifically selecting patients who have received an annual physical examination to represent the overall general population may have been biased toward those with more health access or literacy and could have influenced the lower obesity rates observed in our annual physicals group when compared with the national rates. Furthermore, regional differences in obesity trends could play a major role in limiting the generalizability of our data as the trends observed in our metropolitan urban area may differ from other areas of the country with higher levels of obesity. Despite these limitations, this observational study used sound design and statistical methodology, which determined the trajectory of BMI levels and obesity rates in our population undergoing TKA compared with those of the general population in recent years. Furthermore, our access to a large and comprehensive patient record database allowed us to be confident in the reliability and validity of our data.

Conclusions

Although high BMI remains a significant risk factor for osteoarthritis and the need for TKA, it has remained relatively stable for patients at our institution who were indicated for this procedure. Nonetheless, these patients are generally more obese than the general population. As the demand for TKA continues to rise in the United States, patients with obesity must continue to be optimized before undergoing a surgical procedure. Physicians need to continue in their efforts to educate patients on weight management and healthy lifestyles to potentially delay the need for a surgical procedure. ■

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