

The Dramatic Increase in Total Knee Replacement Utilization Rates in the United States Cannot Be Fully Explained by Growth in Population Size and the Obesity Epidemic

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Background: Total knee replacement utilization in the United States more than doubled from 1999 to 2008. Although the reasons for this increase have not been examined rigorously, some have attributed the increase to population growth and the obesity epidemic. Our goal was to investigate whether the rapid increase in total knee replacement use over the past decade can be sufficiently attributed to changes in these two factors.

Methods: We used data from the Nationwide Inpatient Sample to estimate changes in total knee replacement utilization rates from 1999 to 2008, stratified by age (eighteen to forty-four years, forty-five to sixty-four years, and sixty-five years or older). We obtained data on obesity prevalence and U.S. population growth from federal sources. We compared the rate of change in total knee replacement utilization with the rates of population growth and change in obesity prevalence from 1999 to 2008.

Results: In 2008, 615,050 total knee replacements were performed in the United States adult population, 134% more than in 1999. During the same time period, the overall population size increased by 11%. While the population of forty-five to sixty-four-year-olds grew by 29%, the number of total knee replacements in this age group more than tripled. The number of obese and non-obese individuals in the United States increased by 23% and 4%, respectively. Assuming unchanged indications for total knee replacement among obese and non-obese individuals with knee osteoarthritis over the last decade, these changes fail to account for the 134% growth in total knee replacement use.

Conclusions: Population growth and obesity cannot fully explain the rapid expansion of total knee replacements in the last decade, suggesting that other factors must also be involved. The disproportionate increase in total knee replacements among younger patients may be a result of a growing number of knee injuries and expanding indications for the procedure.

Clinical Relevance: The dramatic increase in total knee replacement utilization has implications for manpower, health-care financing, and the clinical management of patients who have advanced osteoarthritis of the knee.

Total knee replacement utilization in the United States more than doubled in the period from 1999 to 2008¹. More than 600,000 total knee replacements were performed in 2008, incurring an aggregate cost of more than \$9 billion¹. In fact, total knee replacements had the highest aggregate cost among the top ten most rapidly increasing procedures from 2004 to 2007². These dramatic increases in total knee replacement utilization, as well as the associated costs, are projected to continue

into the future^{3,4}. Past studies that have examined the increasing utilization of total knee replacements have noted that this increase is highest among younger patients (i.e., patients younger than sixty-five years of age)⁵⁻⁷. However, these studies have been mainly descriptive and the reasons for the growing number of total knee replacements performed each year remain poorly understood.

The majority of total knee replacements are performed in patients with end-stage knee osteoarthritis. National data on

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the prevalence of knee osteoarthritis are scarce, with most of the data used in these estimates having been collected before 2000⁸. The number of people with knee osteoarthritis in the U.S. has appeared to increase as a result of the aging population and growing levels of obesity⁹.

The strong positive association between obesity and knee osteoarthritis has been studied intensively¹⁰⁻¹³. Given this relationship and the rising levels of obesity in the U.S.¹⁴, some have suggested that rising obesity rates have contributed to increasing total knee replacement use^{15,16}. Crowninshield et al. suggested that population growth, especially among the elderly, has led to an increasing number of joint replacements¹⁵. These assertions have not been examined rigorously. If total knee replacement indications and patterns of use among people with knee osteoarthritis were to remain unchanged, increases in the number of people in the U.S. with knee osteoarthritis (due to obesity and population growth) would likely lead to parallel increases in the number of total knee replacements performed. Our goal was to investigate whether increases in total knee replacement utilization from 1999 to 2008 in the U.S. can be solely explained by population growth and increased obesity prevalence.

Materials and Methods

Analytic Overview

The percent increase in total knee replacement utilization for different age groups (eighteen to forty-four years, forty-five to sixty-four years, and sixty-five years of age or older) from 1999 to 2008 was estimated by comparing the number of total knee replacements performed each year (from 2000 to 2008) with the number of total knee replacements performed during 1999. Increases in population size (compared with the population size reported in 1999) and prevalence of obesity (compared with the prevalence from 1999 to 2000) were calculated in a similar fashion. We compared the magnitude of changes in total knee replacement utilization to the changes over the same period with regard to population and obesity. Analyses were performed on the overall population and stratified by age group.

Data Sources

Total Knee Replacement Utilization Estimates

Data estimating the number of total knee replacements performed each year from 1999 to 2008 were obtained from the Nationwide Inpatient Sample (NIS), a database released by the Healthcare Cost and Utilization Project (HCUP)¹. The NIS is the largest database of inpatient care in the U.S., gathering data from 8 million hospitalizations annually at more than 1000 hospitals in forty-two states and approximating a 20% stratified sample¹⁷.

Total knee replacements were defined on the basis of the International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM) procedure code of 81.54 (total knee replacement). Yearly total knee replacement utilization was stratified by age group (eighteen to forty-four years, forty-five to sixty-four years, and sixty-five years or older).

Population Estimates

Population estimates were based on the National Center for Health Statistics (NCHS) Bridged-Race Estimates, obtained through the Centers for Disease Control and Prevention (CDC) Wide-Ranging Online Data for Epidemiologic Research (WONDER) online database system¹⁸. Yearly July 1st population estimates for the years 1999 through 2008 were stratified by age group (ages eighteen to forty-four years, forty-five to sixty-four years, and sixty-five years or older).

Obesity Estimates

Trends in obesity during the same ten-year period were estimated with use of data from the National Health and Nutrition Examination Survey (NHANES),

a national cross-sectional survey conducted by the Centers for Disease Control and Prevention¹⁹. The prevalence of obesity, defined as the proportion of the population who had a body mass index (BMI) ≥ 30 kg/m², was obtained in two-year intervals from 1999 through 2008 (1999 through 2000, 2001 through 2002, 2003 through 2004, 2005 through 2006, and 2007 through 2008). These obesity data were stratified by age group (ages eighteen to forty-four years, forty-five to sixty-four years, and sixty-five years or older).

Comparing Increased Total Knee Replacement Utilization to Growth in Population and Obesity Prevalence

We estimated the increases in the population size of obese and non-obese cohorts by applying estimates of obesity prevalence to population estimates by age group at each time point. We then compared these changes to the increase in total knee replacement utilization over the same ten-year period. We conducted our comparisons both for the overall population and for the specific age groups.

To evaluate whether, assuming that all other factors remain constant, obesity and population changes alone could account for the ten-year increase in total knee replacement utilization, we combined 1999 total knee replacement utilization estimates with the ten-year percent change in population size. From these data, we projected the number of expected total knee replacements in 2008, stratified by age group and obesity status. We then compared these projections with the actual number of total knee replacements performed in 2008.

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Results

Changes in Population Size

The fluctuations in population size during the decade of 1999 through 2008, stratified by age group, are shown in Figure 1. Overall, the U.S. adult population (eighteen years of age or older) increased by 11% over the decade. The increase in population differed by age group. The lowest increase in population (1%) during the ten-year period was in persons who were eighteen to forty-four years of age. This increase was followed by the cohort that was sixty-five years of age or older, who had an estimated increase in population size of 12%. The greatest increase in population size over the time period from 1999 to 2008 was seen in the population group that was forty-five to sixty-four years of age (29%).

Changes in Obesity Profile

The overall prevalence of obesity increased from 29.6% in 1999 to 2000 to 33.0% in 2007 to 2008. The greatest relative change in obesity prevalence was seen in younger persons; the prevalence of obesity increased by 15% among those who were eighteen to forty-four years of age. Relative increases in obesity prevalence did not exceed 5% in other age groups, with increases of 5% and 3%, respectively, for those who were forty-five to sixty-four years of age and those who were sixty-five years of age or older.

The ten-year changes in the size of the obese and non-obese cohorts, stratified by age group, are depicted in Figure 2. Among all age groups, the number of obese persons increased by 23%, while the number of non-obese individuals increased by 4%. Those who were forty-five to sixty-four years of age experienced the greatest ten-year population increase within both the obese (32%) and non-obese (23%) cohorts.

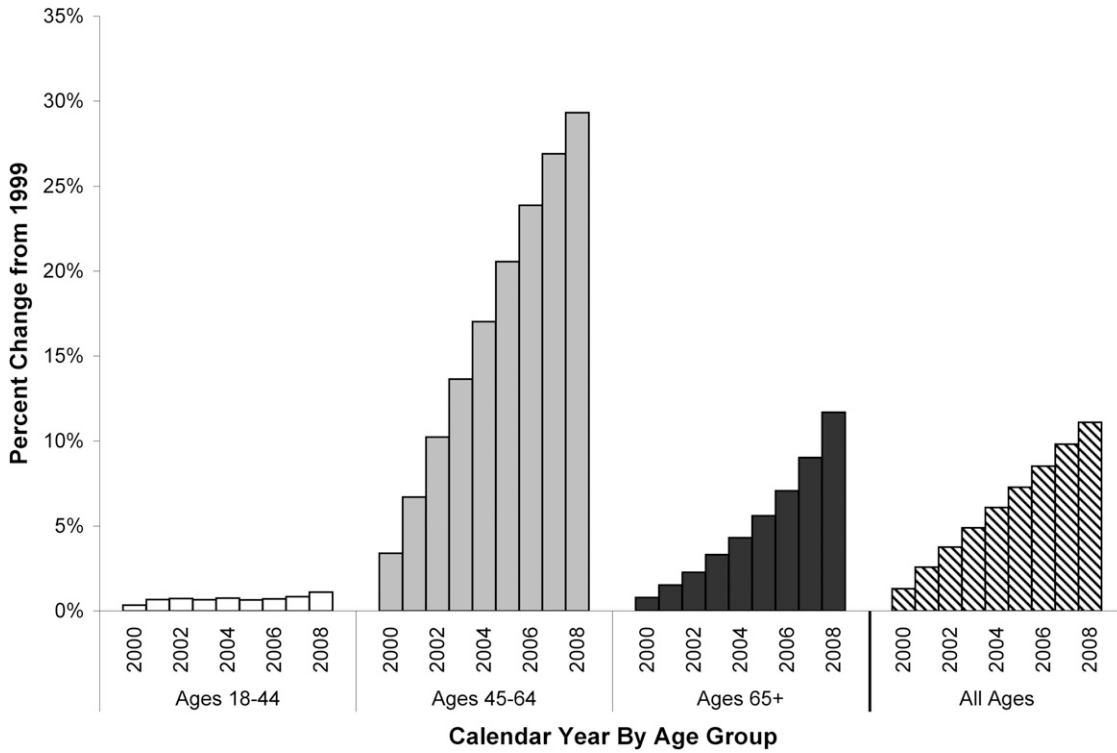


Fig. 1

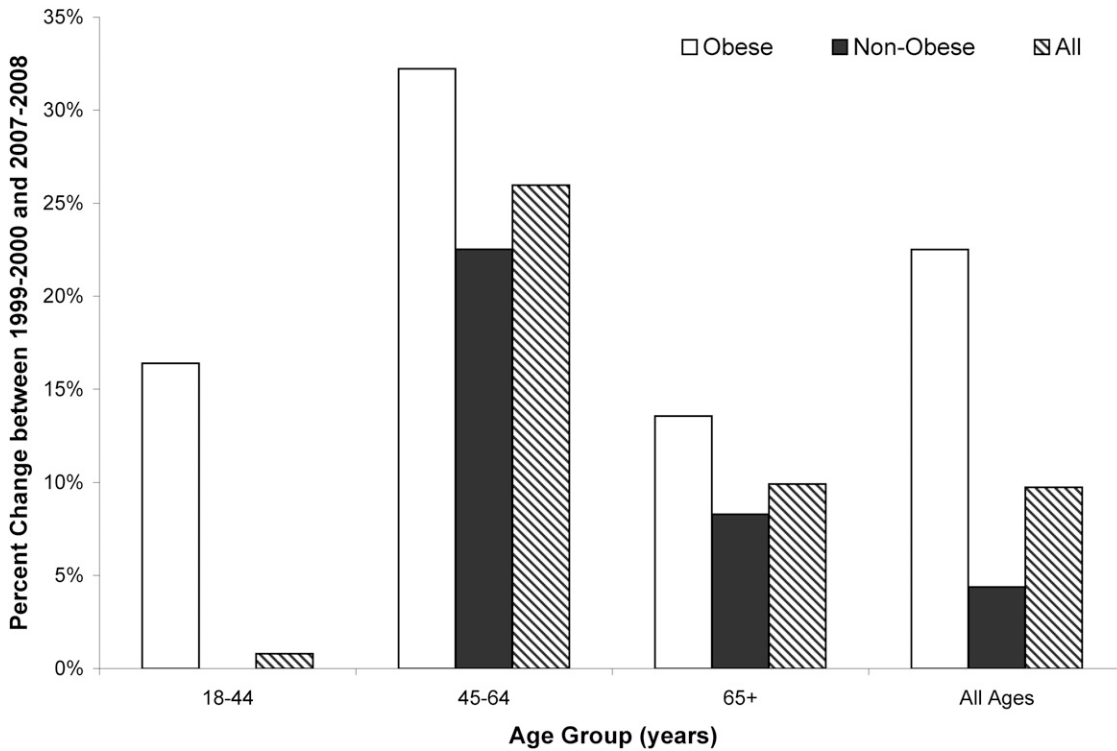


Fig. 2

Fig. 1 Changes in population size by age group, 1999 to 2008. Each bar represents the percent change in population size of the given age group in the given year, compared with the population size of that age group in 1999. **Fig. 2** Changes in population size from the period of 1999 to 2000 to the period of 2007 to 2008 by obesity status and age group. Each bar represents the percent change in obese, non-obese, or total population size from the period of 1999 to 2000 to the period of 2007 to 2008 for the given age group. There is no bar for non-obese eighteen-to-forty-four-year-olds because the percent change for that group was less than zero.

TABLE I Projected Number of 2008 Total Knee Replacements Versus Actual 2008 Estimates

Age Group (yr)	Projections of 2008 Total Knee Replacement Use Given the Change in Total Knee Replacement Use from 1999 to 2008 Can Be Explained by Each Population Group*			Actual Estimates of 2008 Total Knee Replacement Use
	Overall Population	Non-Obese Population	Obese Population	
18 to 44	5,269	4,964	6,064	11,422
45 to 64	102,876	97,461	105,184	252,604
65+	198,656	192,598	202,014	351,024
All ages	291,796	274,130	321,708	615,050

*Each projection is calculated by multiplying the ten-year percent change for the given obesity and age group (see Fig. 2) by the number of total knee replacements performed in 1999 for the given age group. The final column contains actual estimates of total knee replacement use in 2008.

Change in Utilization of Total Knee Replacement and Its Relationship to Changes in Population Size and Obesity

In 2008, 615,050 total knee replacements were performed in the U.S. population of individuals who were eighteen years of age or older, representing a 134% change from 1999 (262,601 total knee replacements; Fig. 3). In the same ten-year period, the overall adult obese population grew 23% and the non-obese population grew 4%.

Increases in total knee replacement utilization varied by age group (Fig. 4). The number of total knee replacements that were performed from 1999 through 2008 increased 119% in the cohort of individuals who were eighteen to forty-four years of age, 218% in the cohort of individuals who were forty-five to sixty-four years of age, and 97% in the cohort of persons who were sixty-five years of age or older. These variations in growth rates led to a redistribution of the number of total knee

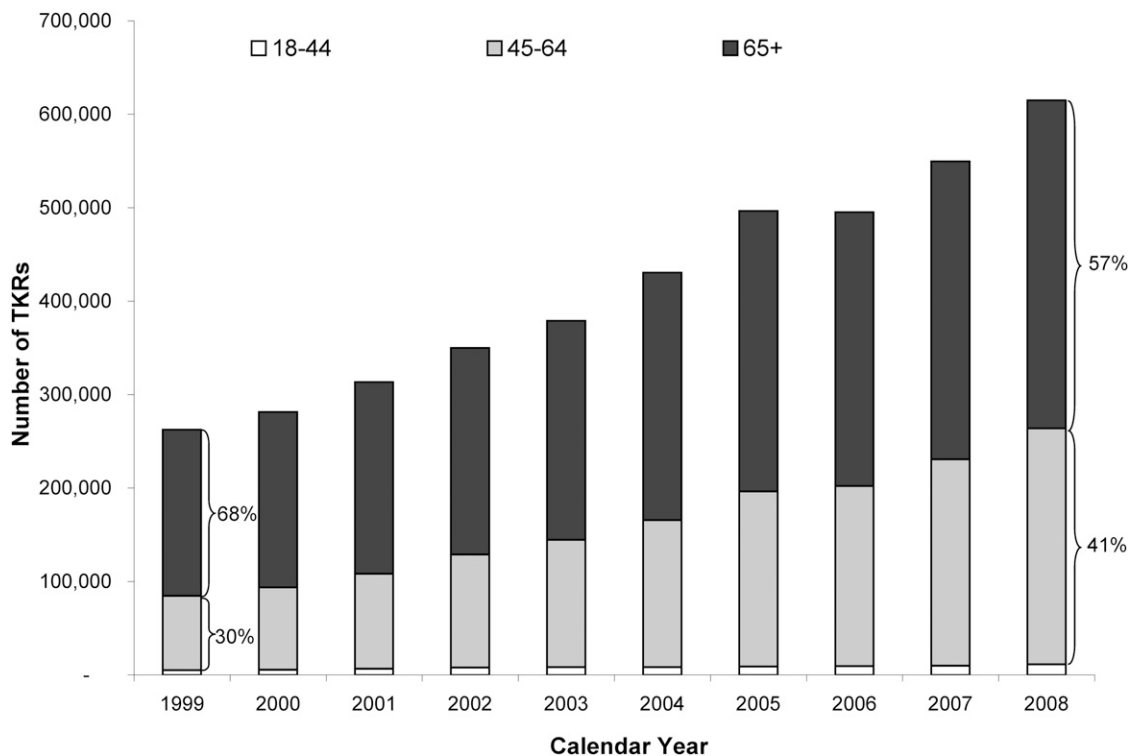


Fig. 3

Total knee replacement (TKR) utilization by age group, 1999 to 2008. Each bar represents the number of total knee replacements performed in the given year, from 1999 to 2008. Different shaded regions represent different age groups. The forty-five to sixty-four-year-old age group represented 30% of total knee replacement use in 1999 and 41% in 2008. The sixty-five-years-or-older age group represented 68% of total knee replacement use in 1999 and 57% in 2008.

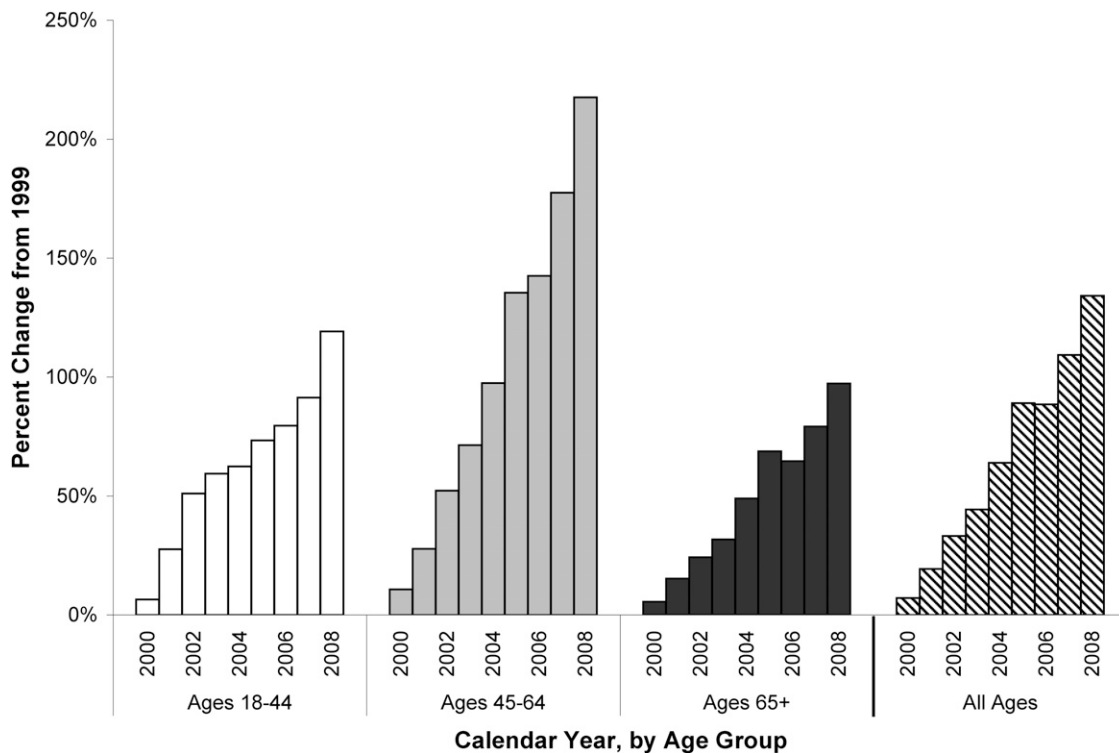


Fig. 4

Changes in total knee replacement utilization by age group, 1999 to 2008. Each bar represents the percent change of total knee replacements performed within the given age group in the given year, compared with the number of total knee replacements performed in that age group in 1999.

replacements performed within each age stratum over the decade (Fig. 3). The forty-five to sixty-four-year-old age group represented 30% of the total knee replacements performed in 1999 compared with 41% in 2008. Meanwhile, the individuals who were sixty-five years of age or older accounted for 68% of total knee replacements in 1999 and 57% in 2008.

We applied the observed 11% population increase from 1999 to 2008 to the 1999 total knee replacement utilization estimate to project an estimated 291,796 total knee replacements in 2008 (Table I). This represents fewer than half of the actual number performed that year (615,050 total knee replacements), indicating that population growth alone cannot account for the ten-year increase in total knee replacement utilization. We performed similar projections using the percent change in population stratified by obesity status to account for differing rates of total knee replacement use among obese and non-obese individuals. We used the 4% and 23% ten-year increases among non-obese and obese individuals, respectively, as minimum and maximum predicted changes in total knee replacement use from 1999 to 2008. Even assuming the maximum 23% increase, the projected total number of total knee replacements in 2008 would only approach 321,708. The assumption that increases in population size and obesity prevalence over time can account for the growth in total knee replacement use, if all other factors remain constant, was thus inconsistent with the 134% observed increase in total knee replacement utilization over the last decade.

Discussion

Total knee replacement utilization more than doubled during the decade from 1999 to 2008. While total knee replacement utilization increased in all age groups, increases were largest among people who were forty-five to sixty-four years of age, for whom total knee replacement utilization more than tripled. Among those who were sixty-five years of age or older, total knee replacement use doubled. The proportion of all total knee replacements that were performed on patients who were forty-five to sixty-four years of age increased from 30% to 41%, while the proportion of all total knee replacements performed on patients who were sixty-five years of age or older dropped from 68% to 57%. These findings are consistent with past research, which indicated that a growing number of young patients (i.e., younger than sixty-five years) are receiving total knee replacements^{3,6,7}.

The ten-year increases in population size among obese and non-obese cohorts were only 23% and 4%, respectively. When we compared these changes with the 134% change in the number of total knee replacements performed over the same ten-year period, our findings suggested that, if all other factors remained constant, the rapid expansion of use of total knee replacements cannot be fully explained by changes in population size and obesity prevalence. Consequently, our data suggest that other factors, including expanding indications for total knee replacement and shifting patterns of total knee replacement use among those with osteoarthritis, must be involved in the increasing total knee replacement utilization over the past decade.

The disproportionate increase in the number of total knee replacements among younger patients points toward several other plausible explanations for the rapid growth in total knee replacement use during the past ten years. First, a more active U.S. population and an increase in sports-related injuries¹⁵ may partially explain the rising number of individuals who are receiving total knee replacements before the age of sixty-five years, since many studies have shown that people who have sports-related knee injuries early in life are at an increased risk of the development of knee osteoarthritis in their forties and fifties²⁰⁻²⁶. Second, indications for total knee replacement may have expanded over time to include younger patients, given that newer prosthetic components are thought to last longer and withstand greater levels of activity than previous ones could²⁷⁻²⁹. Additionally, patients with osteoarthritis of the knee may be considered as candidates for total knee replacement at younger ages in response to recent data suggesting that younger age and better preoperative health are associated with more favorable outcomes after total knee replacement³⁰⁻³². Postoperative complications, in particular infection, have diminished considerably over the thirty-year history of total knee replacement³³, resulting in diminished concerns about adverse outcomes for younger patients. Third, the increased volume of total knee replacement may also be partially explained by the greater demand for total knee replacement by patients who, having been targeted by direct-to-consumer advertising, wish to maintain or resume higher levels of physical activity²⁹. These three factors and others may have resulted in changes in both the prevalence of knee osteoarthritis and patterns of total knee replacement use among patients with osteoarthritis of the knee during the past decade. The ability of these factors to explain the dramatic increase in total knee replacement utilization merits further investigation, as such findings have important implications for future trends.

Our analysis has some limitations. Population, obesity, and total knee replacement utilization data were each obtained from a different source, compromising the ability to compare changes between the three trends. In addition, we relied only on past data, which may not be indicative of future trends. In fact, future estimates indicate an impending reduction in U.S. population size as the population of “baby boomers” ages and is

replaced by age cohorts with lower birth rates³⁴. Finally, we have limited our analysis to total knee replacement use, and did not include trends related to unicompartmental knee replacements.

Analysis of total knee replacement utilization must account for the appropriateness of the procedure. It has been shown that utilization of total knee replacement in the U.S. is greater than that in some European countries, despite a similar prevalence of osteoarthritis³⁵. Conversely, a growing number of studies suggest that there is a substantially lower utilization of total knee replacement among several subpopulations within the U.S., including racial minorities³⁶⁻³⁸. Further research to explicate these patterns of utilization will be critical in developing a sound policy response to the trends we have reported.

In summary, we have shown that the increase in utilization of total knee replacement cannot be fully explained by the growth in population size and the obesity epidemic. The recent increase is likely related to a multitude of factors, including a growing prevalence of sports-related knee injuries and expanded indications for total knee replacement due to both patient and surgeon preferences. These data may be helpful to physicians and policy makers in planning for the delivery of total knee replacement in the future. ■

Note: All authors had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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