Functional Gain and Pain Relief After Total Joint Replacement According to Obesity Status

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Background: Obesity has been associated with lower function and more pain before and after total hip or knee replacement (THR or TKR). We examined the changes between preoperative and postoperative function and pain in a large representative U.S. cohort to determine if there was a relationship to obesity status.

Methods: Preoperative and 6-month postoperative data on function (Short Form-36 Physical Component Summary [PCS] score), joint pain (Hip disability and Osteoarthritis Outcome Score and Knee injury and Osteoarthritis Outcome Score), and body mass index (BMI) were collected from a national sample of 2,040 patients who had undergone THR and 2,964 who had undergone TKR from May 2011 to March 2013. Preoperative and postoperative function and pain were evaluated according to BMI status, defined as under or of normal weight, overweight, obese, severely obese, or morbidly obese.

Results: Patients undergoing THR were an average of 65 years of age; 59% were women, 94% were white, and 14% were severely or morbidly obese. A greater obesity level was associated with a lower (worse) PCS score at baseline and 6 months postoperatively. Severely and morbidly obese patients had less postoperative functional gain than the other BMI groups. A greater obesity level was associated with more pain at baseline but greater postoperative pain relief, so the average postoperative pain scores did not differ significantly according to BMI status. Patients undergoing TKR had an average age of 69 years; 61% were women, 93% were white, and 25% were severely or morbidly obese. A greater obesity level was associated with a lower PCS score at baseline and 6 months. The postoperative gain in PCS score did not differ by BMI level. A greater obesity level was associated with worse pain at baseline but greater pain relief at 6 months, so the average pain scores at 6 month were similar across the BMI levels.

Conclusions: Six months after total joint replacement (TJR), severely or morbidly obese patients reported excellent pain relief and substantial functional gain that was similar to the findings in other patients. While obesity is associated with a greater risk of early complications, obesity in itself should not be a deterrent to undergoing TJR to relieve symptoms.

Level of Evidence: Therapeutic Level II. See Instructions for Authors for a complete description of levels of evidence.

Peer Review: This article was reviewed by the Editor-in-Chief and one Deputy Editor, and it underwent blinded review by two or more outside experts. It was also reviewed by an expert in methodology and statistics. The Deputy Editor reviewed each revision of the article, and it underwent a final review by the Editor-in-Chief prior to publication. Final corrections and clarifications occurred during one or more exchanges between the author(s) and copyeditors.

As the prevalence of obesity continues to grow in the U.S.¹, obesity-related musculoskeletal problems and disabilities, such as severe knee and hip osteoarthritis, are expected to increase. Higher body mass index (BMI) has been associated with a higher risk of osteoarthritis at the knee² and hip^{3,4} and has been directly related to total joint replacement (TJR) use. Over the past 30 years, the number of TJRs, particularly total hip replacement (THR) and total

knee replacement (TKR), has been increasing annually, following a trend similar to that of adult obesity⁴. A greater understanding of the role that obesity plays in patient-reported functional gain and pain relief after TJR is critical to inform the timing of the surgery, patient expectations, and patient-surgeon shared decisions.

Previous research on the associations among obesity, osteoarthritis, and TJR outcome has focused on revision, postoperative

Disclosure: This research was supported by Grant P50HS018910 from the Agency for Healthcare Research and Quality (AHRQ). On the **Disclosure of Potential Conflicts of Interest** forms, which are provided with the online version of the article, one or more of the authors checked “yes” to indicate that the author had a relevant financial relationship in the biomedical arena outside the submitted work (<http://links.lww.com/JBJS/D419>).

complications, and activity level⁵. While prior studies have demonstrated higher rates of complications after TJR among obese patients, studies have also shown notable variations in functional gains after TJR⁵⁻¹⁰. To our knowledge, all previous analyses of TJR outcomes in relation to obesity relied on data from international studies of patients who were older and less obese than current U.S. patients and used data from single high-volume institutions with small numbers of patients in the morbidly obese group. They were limited by patient selection bias or by the use of data from patients who underwent surgery more than 10 years ago and thus were not reflective of today's TJR population. In addition, key risk factors for poorer post-TJR function, such as preoperative emotional health and pain in other joints, were usually not included¹¹.

In an era of value-based payment in which early complications, pain relief, and improvement in function are used to assess surgical impact, surgeons need a better understanding of the role of BMI in symptom relief to facilitate patient-surgeon communication, help patients set expectations, and assist shared patient-surgeon decision-making on the timing of the surgery. To address this need, we analyzed preoperative and postoperative data from the FORCE-TJR (Function and Outcomes Research for Comparative Effectiveness in Total Joint Replacement) cohort, a large U.S. nationally representative cohort of patients treated with TJR. Our aim was to evaluate the extent to which patients with various levels of obesity benefit from TJR with respect to pain relief and functional improvement.

Materials and Methods

Data Source and Data Collection

FORCE-TJR is a large, prospective, national cohort of TJR patients^{12,13} enrolled from diverse high-volume centers and >100 community orthopaedic practices, distributed across 22 states in the U.S. The FORCE-TJR cohort was funded by the Agency for Healthcare Research and Quality (AHRQ) to answer multiple research questions including: What is the relative role of body mass index (BMI) on postoperative functional status? Participating surgeons invited all of their TJR patients to be included in the FORCE-TJR cohort if they chose to, and preoperative data were gathered from both the surgeons and the patients. Patients are followed at routine postoperative intervals (for example, at 6, 12, 24, and 36 months) directly by FORCE research staff for collection of patient-reported outcomes. Approvals for participation in FORCE-TJR were obtained from respective institutional review boards. Patients consented prior to participation in FORCE-TJR.

Study Population

We identified the first 2,964 patients who underwent primary unilateral TKR and the first 2,040 who underwent primary unilateral THR between May 2011 and March 2013 and completed the 6-month postoperative questionnaire. These patients were treated by a total of 111 orthopaedic surgeons and represented >85% of all enrolled patients. The inclusion criterion was a primary diagnosis of osteoarthritis; patients were excluded if they had another diagnosis (for example, osteonecrosis or inflammatory arthritis) or had had the TJR for an acute fracture or cancer. The analysis included only patients for whom both preoperative and 6-month post-TJR functional outcome data and valid body weight and height data at the time of the surgery were available.

Measures

Patient-reported data were collected before and at 6 months after surgery using standardized, structured, and validated questionnaires. A multimodal data

collection approach included in-person interviews in the clinic, telephone interviews, mailed paper forms as needed, and online surveys according to patient preference. Data relevant to this analysis included physical function, joint pain, BMI, and a number of covariates such as sociodemographic characteristics, mental health, medical comorbidities, and musculoskeletal burden of illness. Key measures are described below.

Patient physical function was measured using the Short Form-36 Health Survey (SF-36) Physical Component Summary (PCS) score¹⁴ at baseline and 6 months, and mental health was measured with the SF-36 Mental Component Summary (MCS) score at the same time points¹⁴. PCS and MCS scores range from 0 to 100 with a higher value indicating better function or mental health.

Pain severity of both the operatively treated and the contralateral hip was measured using the Hip disability and Osteoarthritis Outcome Score (HOOS)¹⁵. The HOOS ranges from 0 (worst pain) to 100 (no pain).

The severity of the pain in both the involved and the contralateral knee was measured using the Knee injury and Osteoarthritis Outcome Score (KOOS). The ranges and interpretation of the KOOS scores are similar to those for the HOOS scores.

Patient body weight and height were measured in the clinic or self-reported by the patient at the time of surgery. BMI was calculated as body weight in kilograms divided by squared body height in meters (kg/m²). According to the commonly accepted World Health Organization classification scheme¹⁶, patients were grouped according to their preoperative BMI as under or of normal weight (≤ 24.99 kg/m²), overweight (25.00 to 29.99 kg/m²), obese (30.00 to 34.99 kg/m²), severely obese (35.00 to 39.99 kg/m²), or morbidly obese (≥ 40.00 kg/m²).

Patient sociodemographic variables included sex, age, race, ethnicity, marital status, education, employment, household income, and type of medical insurance. The musculoskeletal burden of illness was measured by quantifying the number of hips and knees with moderate or severe pain (according to the HOOS or KOOS score) as well as moderate or severe pain in the low back (according to the Oswestry Disability Index)¹⁷. Medical comorbidities were quantified using the modified Charlson Comorbidity Index¹⁸, with the exclusion of musculoskeletal conditions to avoid redundancy with the aforementioned index for musculoskeletal burden.

Statistical Analysis

We summarized the patient characteristics (Table I) as well as the preoperative, 6-month postoperative, and preoperative-to-postoperative changes in PCS and pain scores (Table II) according to the patient's BMI classification. Distributional characteristics of the preoperative and postoperative PCS and pain scores, such as range and mode, were examined and illustrated using kernel density plots (Figs. 1 and 2). Changes between the preoperative and postoperative assessments were also evaluated using linear mixed models that adjusted for the clustering of patients within individual clinics, with and without adjustment for other covariates (Table II). Covariates included baseline function and pain score, sex, age, race, household income, education, living alone, type of insurance, medical comorbidities, low back pain, number of other painful joints, and surgical volume of the hospital. Changes in PCS and pain scores of patients operated on in the same clinic were considered independently and identically normally distributed. Models assumptions were carefully examined, and no apparent violations were found.

Results

THR

The 2,040 patients who underwent THR had an average age of 65 years; 59% were women, 94% were white, 25% had a high school education or less, 35% had an annual household income of $\leq \$45,000$, and 50% had Medicare insurance (Table I). Forty-two percent had ≥ 1 comorbid medical conditions, 35% had moderate or severe low-back pain, and 35% had ≥ 1 other painful knee or hip joints.

TABLE I Patient Characteristics by BMI Group* and Overall

Characteristic	Under or Normal Weight	Overweight	Obese	Severely Obese	Morbidly Obese	Total
THR group (n = 2,040)						
Male (%)	30.2	48.5	45.5	38.2	33.3	41.4
Age† (yr)	66.7 (11.2)	66.2 (10.1)	63.8 (9.9)	63.0 (9.3)	60.0 (9.1)	65.2 (10.4)
White race (%)	94.0	94.4	94.3	92.7	94.4	94.1
Education (≤high school) (%)	22.5	23.6	26.3	32.8	28.4	25.1
Household income (≤\$45,000) (%)	31.5	33.3	40.0	36.5	39.1	35.0
Medicare insurance (%)	53.1	52.7	48.1	45.5	33.0	50.2
Living alone (%)	25.3	21.2	24.9	24.5	25.6	23.6
Current smoker (%)	7.5	6.2	8.7	9.5	6.7	7.5
≥1 medical comorbidities (%)	35.9	43.0	42.6	49.8	52.2	42.2
Moderate or severe low-back pain (%)	31.2	35.7	33.0	42.5	45.0	35.0
≥1 other painful joints (%)	31.1	31.7	38.5	41.5	46.1	34.7
Baseline MCS score†	51.5 (12.3)	51.5 (12.1)	50.3 (12.4)	49.9 (11.6)	46.5 (14.8)	50.9 (12.3)
TKR group (n = 2,964)						
Male (%)	30.3	46.1	40.7	33.0	29.8	38.9
Age† (yr)	69.2 (10.1)	68.7 (9.4)	66.7 (8.6)	64.4 (8.2)	62.5 (7.8)	67.0 (9.2)
White race (%)	95.2	93.7	92.9	90.8	88.6	92.7
Education (≤high school) (%)	25.5	30.1	35.2	32.6	31.9	31.5
Household income (≤\$45,000) (%)	36.6	34.8	40.2	42.3	47.7	38.7
Medicare insurance (%)	60.9	61.2	55.8	48.0	44.0	56.0
Living alone (%)	22.7	21.9	21.4	24.3	27.9	22.8
Current smoker (%)	4.6	4.7	3.6	4.9	5.6	4.5
≥1 medical comorbidities (%)	43.5	48.3	47.4	51.7	57.4	48.7
Moderate or severe low-back pain (%)	21.7	26.9	25.8	29.3	34.3	26.9
≥1 other painful joints (%)	23.8	28.3	30.9	39.2	41.9	31.4
Baseline MCS score†	53.8 (10.8)	53.2 (11.1)	52.2 (12.1)	51.5 (12.3)	49.4 (12.7)	52.4 (11.8)

*BMI was ≤24.99 kg/m² for under or normal weight, 25.00 to 29.99 kg/m² for overweight, 30.00 to 34.99 kg/m² for obese, 35.00 to 39.99 kg/m² for severely obese, and ≥40.00 kg/m² for morbidly obese. †The values are given as the mean with the standard deviation in parentheses.

Of the patients who underwent THR, 26% were under or of normal weight, 37% were overweight, 22% were obese, 10% were severely obese, and 4% were morbidly obese. Severely and morbidly obese patients were more likely to be female ($p = 0.001$) and were younger ($p = 0.006$) than normal weight or obese patients. They had more medical comorbidities ($p < 0.001$) and were more likely to have moderate or severe low-back pain ($p = 0.007$) and other painful joints ($p < 0.001$). Morbidly obese patients had lower mental health scores compared with the patients in the other BMI groups ($p = 0.006$).

Greater levels of obesity were associated with lower (worse) PCS scores at baseline ($p < 0.001$) and 6 months after THR (trend test, $p < 0.001$) (Table II). However, the mean preoperative-to-postoperative changes in PCS scores did not significantly differ by BMI status ($p = 0.07$), although the mean change was slightly lower among severely and morbidly

obese patients (Table II and Fig. 1-A). Differences in postoperative gain in the PCS score became greater after covariate adjustment, with severely and morbidly obese patients having substantially less gain than other patients ($p < 0.001$).

The patients with greater levels of obesity had poorer baseline HOOS pain scores (trend test, $p < 0.001$) but larger improvement between baseline and the 6-month post-THR pain score (trend test, $p < 0.001$) (Table II and Fig. 1-B). At 6 months after the THRs, the patients had excellent pain scores regardless of their BMI status, and the mean pain scores were within a very close range. For example, the baseline score for the morbidly obese patients was 12.8 points lower (worse) than that for the underweight or normal-weight patients (38.2 versus 51.0 points), but the difference was reduced to 3.4 points at 6 months (88.4 versus 91.8 points). After covariate adjustment, preoperative-to-postoperative pain relief did not significantly differ by BMI level.

TABLE II Patient-Reported Physical Function and Pain Before and 6 Months After TJR by BMI Group*

		PCS Score†			
	No.	Baseline	6 Mo	Preop.-Postop. Change	
				Absolute	Adjusted§
THR					
Under or normal weight	530	32.4 (31.7, 33.2)	46.5 (45.6, 47.4)	14.1 (13.2, 15.0)	14.0 (13.1, 14.8)
Overweight	763	32.7 (32.0, 33.2)	45.7 (45.0, 46.4)	13.1 (12.4, 13.8)	13.2 (12.5, 13.9)
Obese	453	30.2 (29.4, 31.0)	44.8 (43.9, 45.7)	14.6 (13.6, 15.5)	13.3 (12.4, 14.2)
Severely obese	204	28.3 (27.1, 29.4)	41.2 (39.8, 42.6)	12.9 (11.4, 14.4)	10.8 (9.5, 12.0)
Morbidly obese	90	26.6 (25.1, 28.1)	39.6 (37.6, 41.6)	13.0 (10.8, 15.2)	9.6 (7.7, 11.4)
All patients	2,040	31.3 (31.0, 31.7)	45.0 (44.6, 45.4)	13.7 (13.2, 14.1)	13.0 (12.5, 13.6)
TKR					
Under or normal weight	396	35.1 (34.3, 36.0)	44.7 (43.8, 45.6)	9.5 (8.7, 10.4)	10.8 (9.9, 11.6)
Overweight	978	34.3 (33.8, 34.8)	44.2 (43.6, 44.8)	9.9 (9.3, 10.4)	10.9 (10.3, 11.5)
Obese	861	33.0 (32.5, 33.5)	42.3 (41.7, 43.0)	9.3 (8.7, 9.9)	9.6 (9.0, 10.2)
Severely obese	457	31.3 (30.6, 32.1)	41.1 (40.2, 42.0)	9.8 (9.0, 10.6)	9.0 (8.2, 9.8)
Morbidly obese	272	29.9 (29.0, 30.8)	40.4 (39.3, 41.6)	10.5 (9.4, 11.7)	9.3 (8.3, 10.3)
All patients	2,964	33.2 (32.9, 33.5)	42.9 (42.5, 43.2)	9.7 (9.4, 10.0)	10.1 (9.7, 10.5)

*BMI was ≤ 24.99 kg/m² for under or normal weight, 25.00 to 29.99 kg/m² for overweight, 30.00 to 34.99 kg/m² for obese, 35.00 to 39.99 kg/m² for severely obese, and ≥ 40.00 kg/m² for morbidly obese. †The values are given as the mean with the 95% CI in parentheses. ‡HOOS pain score for THR group and KOOS pain score for TKR group. §Adjusted for baseline score, sex, age, race, education, household income, living alone, type of insurance, medical comorbidities, low back pain, number of other painful joints, and hospital surgical volume using linear mixed models that account for intraclass correlation due to patients clustering within an individual clinic.

TKR

The 2,964 patients who underwent TKR had an average age of 69 years; 61% were women, 93% were white, 32% had a high school education or less, 39% had an annual household income of $\leq \$45,000$, and 56% had Medicare insurance (Table I). In the TKR group, 49% had ≥ 1 comorbid medical conditions, 27% had moderate or severe low-back pain, and 31% had ≥ 1 painful joints other than the replaced joint or in the low back.

Of the patients who underwent TKR, 13% were under or of normal weight, 33% were overweight, 29% were obese, 15% were severely obese, and 9% were morbidly obese (Table I). Severely and morbidly obese patients were more likely to be female ($p < 0.001$), younger ($p < 0.001$), and of non-white race ($p = 0.001$); to have lower household income ($p = 0.03$) and private insurance ($p < 0.001$); and to live alone ($p = 0.03$). They were more likely to have medical comorbidities ($p < 0.001$), moderate or severe low-back pain ($p = 0.012$), and other painful joints ($p < 0.001$). Morbidly obese patients had worse mental health scores compared with the other BMI groups ($p < 0.001$).

Patients with a greater level of obesity had worse PCS scores at baseline (trend test, $p < 0.001$) and 6 months (trend test, $p < 0.001$) (Table II and Fig. 2-A). However, the change in the PCS score between baseline and 6 months after the TKA did not differ by BMI level ($p = 0.37$), with an overall mean of 9.7 (95% confidence interval [CI] = 9.4, 10.0). The results were robust to covariate adjustment.

Patients with greater levels of obesity had lower (worse) KOOS pain scores at baseline (trend test, $p < 0.001$) but larger improvements between baseline and the 6-month post-TKR pain scores (trend test, $p < 0.001$) (Table II and Fig. 2-B). Similar to the results after the THRs, the pain scores after the TKRs were excellent regardless of BMI status and the mean pain scores were in a very close range at 6 months, except for morbidly obese patients, whose mean score was slightly lower (worse) than the scores in the other groups ($p = 0.02$). The overall mean pain score was 84.5 (95% CI = 83.9, 85.1) at 6 months. Covariate-adjusted preoperative-to-postoperative pain relief was similar to that in the unadjusted analysis.

Discussion

With the increasing prevalence of obesity and TJR use in the U.S. population, a better understanding of the effects of obesity on the function and pain outcomes after TJR is crucial. To fill a gap in knowledge about variations in post-TJR changes in function and pain according to level of obesity, we used data from a large, contemporary U.S. national representative cohort of patients treated with TJR, thereby providing the first norms for U.S. patients. Our analysis demonstrates that severely or morbidly obese patients can have excellent pain relief and substantial functional gain at 6 months after TJR that are similar to the results in nonobese patients. These findings are important as they enable physicians to inform severely and morbidly obese patients about the expected gains in function and pain

TABLE II (continued)

No.	Baseline	6 Mo	Pain Score†‡	
			Preop.-Postop. Change	
			Absolute	Adjusted§
515	51.0 (49.2, 52.7)	91.8 (90.7, 92.9)	40.9 (39.1, 42.7)	42.4 (41.0, 43.7)
745	51.1 (49.8, 52.5)	90.6 (89.7, 91.6)	39.5 (38.0, 41.0)	41.0 (39.8, 42.2)
442	47.3 (45.5, 49.0)	89.7 (88.4, 90.9)	42.5 (40.5, 44.5)	41.0 (39.6, 42.4)
194	45.5 (42.6, 48.4)	88.4 (86.4, 90.5)	43.0 (39.4, 46.5)	40.1 (38.1, 42.1)
86	38.2 (34.0, 42.4)	88.4 (85.6, 91.1)	50.2 (45.9, 54.5)	41.5 (38.6, 44.4)
1,982	49.1 (48.2, 50.0)	90.4 (89.8, 91.0)	41.3 (40.4, 42.3)	41.3 (40.3, 42.2)
371	56.4 (54.6, 58.2)	85.5 (84.1, 87.0)	29.0 (26.9, 31.1)	31.7 (30.0, 33.44)
927	55.4 (54.2, 56.5)	85.8 (84.8, 86.7)	30.4 (29.1, 31.7)	32.2 (31.0, 33.3)
817	53.0 (51.8, 54.3)	83.6 (82.4, 84.7)	30.5 (29.1, 31.9)	30.3 (29.1, 31.5)
426	50.6 (48.7, 52.4)	84.0 (82.4, 85.6)	33.3 (31.3, 35.2)	31.1 (29.5, 32.6)
251	47.1 (44.8, 49.4)	82.6 (80.3, 84.8)	35.4 (32.8, 38.0)	30.2 (28.2, 32.2)
2,792	53.3 (52.7, 54.0)	84.5 (83.9, 85.1)	31.1 (30.4, 31.9)	31.2 (30.4, 32.0)

Fig. 1

Fig. 2

Fig. 1 Distributional characteristics of PCS (Fig. 1-A) and pain (Fig. 1-B) scores before and after THR. **Fig. 2** Distributional characteristics of PCS (Fig. 2-A) and pain (Fig. 2-B) scores before and after TKR.

relief on average, help them set proper expectations, and work with them to decide the optimal timing of their surgery.

Our data clearly show that patients in all BMI groups had substantial improvements in both pain and function at 6 months after TJR, despite worse preoperative pain and function in patients with greater levels of obesity. While all BMI groups reported substantial functional gains at 6 months after THR, the mean functional gain was slightly lower for severely and morbidly obese patients than for the other patients. However, after TKR, patients with a greater level of obesity reported improvements in both pain scores and function equal to, or greater than, those of the other patients.

Consistent with prior reports, our severely and morbidly obese patients had lower absolute levels of function after THR than patients with lower BMIs^{5,19}. As early as 2000, higher BMIs were reported to be associated with lower activity levels of patients treated with TKR or THR²⁰. Despite pain relief in the surgically treated hip, extremely obese patients may have more coexisting medical and musculoskeletal conditions that limit function. Of note, we previously reported that obese patients are more likely to have advanced arthritic pain in the untreated knee and hips as well as the low back after TKR²¹. Persistent pain in these locations may limit overall function after surgery. Despite these challenges, our severely and morbidly obese patients still reported substantial improvement in function and pain relief following THR.

These U.S. findings are consistent with recent international THR studies. A retrospective study of patients in England and Wales demonstrated significant improvements in function and pain after THR irrespective of BMI, despite higher risks of complications in patients with high BMI²². A study of 4 THR patient cohorts also showed significant postoperative functional gain across all BMI groups, with the authors noting that the gain outweighed the lower postoperative scores achieved in the higher-BMI groups²³. A study employing the New Zealand registry showed that obese and morbidly obese patients had significantly lower post-THR function, the highest revision rate, and the lowest estimated 2-year implant-survival rate. However, the authors compared only postoperative scores—and not preoperative-to-postoperative improvements in scores—among different BMI groups²⁴. Also, patients with high BMI tended to be younger (as was found in our cohort). Surprisingly, the outcomes were best in the overweight group, although no explanation was offered. In our study, post-THR function scores of severely and morbidly obese patients were lower than those of overweight and underweight or normal-weight patients, but the postoperative functional gains were similar.

A recent small cohort study showed no significant difference in post-TKR changes in the Oxford Knee Score or SF-12 PCS or MCS scores between morbidly obese and nonobese patients up to 12 months postoperatively²⁵. Another study demonstrated poorer 1-year post-TKR WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) scores in morbidly obese patients compared with non-morbidly-obese patients but greater improvement 1 year postoperatively in the morbidly obese patients²⁶; that finding is in agreement with our data.

To define gains in pain and function for all patients who undergo TKR or THR in the U.S., we included patients with early complications in our analyses. Obesity and medical comorbidities affect rates of postoperative adverse events⁵. A recent analysis of a large cohort of patients who underwent TKR surgery and were included in the PearlDiver Patient Records Database showed “super” obese patients to have dramatically increased rates of complications after TKR compared with nonobese, obese, and morbidly obese patients²⁷. A study of the Kaiser Permanente Total Joint Replacement Registry demonstrated a higher risk of hospital readmissions within 30 days after THR among morbidly obese patients²⁸. Our own previous data revealed similar associations²⁹. In future research, we will analyze the benefits, with regard to pain relief and functional gain, versus the risks of complications according to the severity of obesity to provide a more comprehensive and balanced picture of the benefit-risk ratio for patients who are considering a TJR.

Our study has several strengths. We used a prospective cohort design with a high postoperative response rate (>85%) to patient-reported measures, high patient retention rate at 6 months, and comprehensive data on comorbidities. As a result, our data are of high quality, and the rates of loss to follow-up and missing data are low. Unlike U.S. studies based on data from a single or a few large academic hospitals, our data were collected through a national network of participating hospitals across the country, representing academic and community hospitals and including 114 surgeons. The data were collected, using uniform standards and informatics infrastructure, by staff well trained to follow the same study protocol. Data collection activities were routinely monitored.

Limitations of our study, similar to those of other studies, are that our cohort included a low percentage of racial and ethnic minorities and patients tended to have higher incomes and educational levels. While these demographics parallel those of patients currently being treated with TJR, future research is needed to specifically address TJR outcomes among minority populations. Also, our analyses used 6-month outcome data. Although unpublished FORCE data have indicated that >85% of surgery’s benefits are reported by 6 months, and this time interval is comparable with the Centers for Medicare & Medicaid Services (CMS) pilot mandate of 9 to 12-month patient-reported outcome measures, long-term follow-up is needed. Future analysis will examine variations in outcomes at 2 years as data become available. It will be of great interest to evaluate how adverse events and trajectories of functional gain and pain relief differ according to level of obesity.

In conclusion, this study of a large representative U.S. cohort of patients treated with TJR supports the conclusion that obesity should not be a deterrent to surgery to relieve hip and knee osteoarthritic symptoms. Our data demonstrate that severely and morbidly obese patients can expect substantial pain relief and improvement in functional activity following successful TJR. However, U.S. patients and surgeons should discuss the association between obesity and an elevated risk of postoperative complications. Future research will examine the

relative benefits and risks of expected pain relief and functional gain versus complications. These U.S. outcome data are important for surgeons who are helping patients to decide whether and when to undergo an elective TJR. ■

NOTE: The authors thank Dr. Sylvie Puig for her editorial assistance with this manuscript and Ms. Wenyun Yang for her preparation of the analytic data set for this study.

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References

- Fryar CD, Carroll MD, Ogden CI. Prevalence of overweight, obesity, and extreme obesity among adults: United States, trends 1960-1962 through 2009-2010. 2012. https://www.cdc.gov/nchs/data/hestat/obesity_adult_09_10/obesity_adult_09_10.htm. Accessed 2017 Mar 3.
- Felson DT, Chaisson CE. Understanding the relationship between body weight and osteoarthritis. *Baillieres Clin Rheumatol*. 1997 Nov;11(4):671-81.
- Cooper C, Inskip H, Croft P, Campbell L, Smith G, McLaren M, Coggon D. Individual risk factors for hip osteoarthritis: obesity, hip injury, and physical activity. *Am J Epidemiol*. 1998 Mar 15;147(6):516-22.
- Wendelboe AM, Hegmann KT, Biggs JJ, Cox CM, Portmann AJ, Gildea JH, Gren LH, Lyon JL. Relationships between body mass indices and surgical replacements of knee and hip joints. *Am J Prev Med*. 2003 Nov;25(4):290-5.
- Springer BD, Parvizi J, Austin M, et al.; Workgroup of the American Association of Hip and Knee Surgeons Evidence Based Committee. Obesity and total joint arthroplasty: a literature based review. *J Arthroplasty*. 2013 May;28(5):714-21. Epub 2013 Mar 19.
- Flugsrud GB, Nordsletten L, Espehaug B, Havelin LI, Meyer HE. Risk factors for total hip replacement due to primary osteoarthritis: a cohort study in 50,034 persons. *Arthritis Rheum*. 2002 Mar;46(3):675-82.
- Karlson EW, Mandl LA, Aweh GN, Sangha O, Liang MH, Grodstein F. Total hip replacement due to osteoarthritis: the importance of age, obesity, and other modifiable risk factors. *Am J Med*. 2003 Feb 1;114(2):93-8.
- Spicer DD, Pomeroy DL, Badenhausen WE, Schaper LA Jr, Curry JI, Suthers KE, Smith MW. Body mass index as a predictor of outcome in total knee replacement. *Int Orthop*. 2001;25(4):246-9.
- Franklin PD, Li W, Ayers DC. The Chitranjan Ranawat Award: functional outcome after total knee replacement varies with patient attributes. *Clin Orthop Relat Res*. 2008 Nov;466(11):2597-604.
- Shepherd EF, Toloza E, McClung CD, Schmalzried TP. Step activity monitor: increased accuracy in quantifying ambulatory activity. *J Orthop Res*. 1999 Sep;17(5):703-8.
- Singh JA, Gabriel SE, Lewallen DG. Higher body mass index is not associated with worse pain outcomes after primary or revision total knee arthroplasty. *J Arthroplasty*. 2011 Apr;26(3):366-374.e1. Epub 2010 Apr 21.
- Ayers DC, Franklin PD. Joint replacement registries in the United States: a new paradigm. *J Bone Joint Surg Am*. 2014 Sep 17;96(18):1567-9.
- Franklin PD, Allison JJ, Ayers DC. Beyond joint implant registries: a patient-centered research consortium for comparative effectiveness in total joint replacement. *JAMA*. 2012 Sep 26;308(12):1217-8.
- Ware JE, Kosinski M, Keller SD. SF-36 physical and mental health summary scales: a user's manual. Boston: The Health Institute; 1994.
- Nilsdotter AK, Lohmander LS, Klässbo M, Roos EM. Hip disability and Osteoarthritis Outcome Score (HOOS)—validity and responsiveness in total hip replacement. *BMC Musculoskelet Disord*. 2003 May 30;4:10. Epub 2003 May 30.
- World Health Organization (WHO). International classification of functioning, disability and health (ICF). 2001. <http://www.who.int/classifications/icf/en/>. Accessed 2017 Mar 3.
- Daltroy LH, Cats-Baril WL, Katz JN, Fossel AH, Liang MH. The North American Spine Society Lumbar Spine Outcome Assessment Instrument: reliability and validity tests. *Spine*. 1996 Mar 15;21(6):741-9.
- Charlson M, Szatrowski TP, Peterson J, Gold J. Validation of a combined comorbidity index. *J Clin Epidemiol*. 1994 Nov;47(11):1245-51.
- Vincent HK, Horodyski M, Gearen P, Vlasak R, Seay AN, Conrad BP, Vincent KR. Obesity and long term functional outcomes following elective total hip replacement. *J Orthop Surg*. 2012 Apr 25;7:16.
- McClung CD, Zahir CA, Higa JK, Amstutz HC, Schmalzried TP. Relationship between body mass index and activity in hip or knee arthroplasty patients. *J Orthop Res*. 2000 Jan;18(1):35-9.
- Ayers DC, Li W, Oatis C, Rosal MC, Franklin PD. Patient reported outcomes after total knee replacement vary on the basis of preoperative coexisting disease in the lumbar spine and other non-operatively treated joints: the need for a musculoskeletal comorbidity index. *J Bone Joint Surg Am*. 2013;95(20):1833-7.
- Jameson SS, Mason JM, Baker PN, Elson DW, Deehan DJ, Reed MR. The impact of body mass index on patient reported outcome measures (PROMs) and complications following primary hip arthroplasty. *J Arthroplasty*. 2014 Oct;29(10):1889-98. Epub 2014 Jun 2.
- Judge A, Batra RN, Thomas GE, Beard D, Javadi MK, Murray DW, Dieppe PA, Dreinhoefer KE, Peter-Guenther K, Field R, Cooper C, Arden NK. Body mass index is not a clinically meaningful predictor of patient reported outcomes of primary hip replacement surgery: prospective cohort study. *Osteoarthritis Cartilage*. 2014 Mar;22(3):431-9. Epub 2014 Jan 11.
- Murgatroyd SE, Frampton CM, Wright MS. The effect of body mass index on outcome in total hip arthroplasty: early analysis from the New Zealand Joint Registry. *J Arthroplasty*. 2014 Oct;29(10):1884-8. Epub 2014 Jun 4.
- Napier RJ, O'Brien S, Bennett D, Doran E, Sykes A, Murray J, Beverland DE. Intraoperative and short term outcome of total knee arthroplasty in morbidly obese patients. *Knee*. 2014 Jun;21(3):784-8. Epub 2014 Feb 26.
- Rajgopal V, Bourne RB, Chesworth BM, MacDonald SJ, McCalden RW, Rorabeck CH. The impact of morbid obesity on patient outcomes after total knee arthroplasty. *J Arthroplasty*. 2008 Sep;23(6):795-800. Epub 2008 Mar 4.
- Werner BC, Evans CL, Carothers JT, Browne JA. Primary total knee arthroplasty in super-obese patients: dramatically higher postoperative complication rates even compared to revision surgery. *J Arthroplasty*. 2015 May;30(5):849-53. Epub 2014 Dec 19.
- Paxton EW, Inacio MC, Singh JA, Love R, Bini SA, Namba RS. Are there modifiable risk factors for hospital readmission after total hip arthroplasty in a US healthcare system? *Clin Orthop Relat Res*. 2015 Nov;473(11):3446-55.
- Ayers DC, Fehring TK, Odum SM, Franklin PD. Using joint registry data from FORCE-TJR to improve the accuracy of risk-adjustment prediction models for thirty-day readmission after total hip replacement and total knee replacement. *J Bone Joint Surg Am*. 2015 Apr 15;97(8):668-71.