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ORIGINAL ARTICLE

Age, gender, obesity, and depression are associated with patient-related pain and function outcome after revision total hip arthroplasty

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Abstract To examine whether patient characteristics predict patient-reported pain and function 2- or 5-years after revision total hip arthroplasty (THA). In a prospective cohort of revision THA patients, we examined whether gender, age, body mass index (BMI), comorbidity (Deyo–Charlson index) and depression predicted moderate–severe hip pain, moderate–severe activity limitation (≥3 activities), dependence on walking aids and use of pain medications, using multivariable regression analysis. Significant predictors of moderate–severe pain at 2- and 5-years were [odds ratio (95% confidence interval)]: female gender, 1.3 (1.0, 1.6) and 1.5 (1.1, 1.9) and age 61–70, 0.7 (0.5, 1.0) and 0.7 (0.5, 1.0; reference (ref),≤60 years). BMI, 30–34.9, 1.4 (1.0, 1.9; ref BMI≤25) and depression, 1.6 (1.0, 2.5) were significantly associated with higher odds of moderate–severe pain at 2 years, but not at 5 years. Significant predictors of nonsteroidal anti-inflammatory drugs (NSAIDs) use 2-years post-revision THA were female gender, 1.4 (1.1, 1 .7), BMI, 30–34.9, 1.4 (1.0, 2.0) and age, 71–80, 0.7 (0.5, 0.9). At 5 years, female gender, 1.6 (1.2, 2.2) was significantly associated with NSAID use. Significant predictors of narcotic use 2-years post-revision THA were older age, 61–70, 0.5 (0.3, 0.7) and 71–80, 0.4 (0.3, 0.7) and depression, 2.4 (1.2, 4.6). At 5 years, women, had significantly higher odds 1.8 (1.1, 2.9) of narcotic use and those in age group 61–70 years, significantly lower odds of narcotic use, 0.4 (0.2, 0.7). Similarly, female gender, older age (>70) and BMI of 30 or higher were each significantly associated with higher odds of moderate–severe activity limitation at both, 2- and 5-years. Depression was associated with higher risk at 2 years, 1.7 (1.1, 2.6) and higher Deyo–Charlson score with a higher risk of moderate–severe activity limitation at 5 years, 1.7 (1.1, 2.7). Obesity and depression, considered modifiable clinical factors, were important independent predictors of pain, functional limitation and use of pain medications, following revision THA.

Keywords Body mass index · Comorbidity · Depression · Function · Pain · Pain medications · Predictors · Total hip arthroplasty

Introduction

Revision total hip arthroplasty (THA) is becoming increasingly common in the USA due to an aging

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population. In 2005, 40,800 revision THAs were performed in the USA, projected to increase by 137% to 96,700 annually by year 2030 [1]. The primary objectives of revision THA are improvement in pain and function, similar to the primary THA [2]. Outcomes following revision THA are not as good as those after the primary THA [3, 4]. A better understanding of the prevalence and predictors of patient-reported outcomes following revision THA is needed.

Most previous studies of functional outcomes in patients with revision THA used physician-based outcome instruments [5–10]. Patient-reported outcomes (such as pain and function), now considered to be the gold standard in understanding arthroplasty outcomes, were reported in a few prospective [11–14] and retrospective studies of revision THA [15, 16]. These studies examined patient characteristics as potential predictors of pain and function outcomes, but were limited to small samples of patients (<300 cases) and reported contradictory results. For example, higher body mass index (BMI) was associated with more pain in one study [14], but no association was found in the other study [11]. Women reported more severe pain than men in one study [11, 13], while a trend towards more severe pain in men was reported in another [12]. Older age was associated with worse function in one study [15], but not associated in another study [16]. The differences in results of these studies is at least partially be due to differences in sample size, time of assessment, confounders included in the analyses, and outcome instruments. These studies suggest that certain demographic and clinical characteristics are related to outcomes following revision THA.

Another postarthroplasty pain outcome that is infrequently studied is the use of pain medications by patients after revision THA for persistent hip pain. There is only one published report of use of pain medications after revision THA [12]. Preoperative psychological distress and preoperative depression have been shown to predict outcomes after knee arthroplasty [17, 18], but to our knowledge, have not been studied in revision THA patients.

The objective of this study was to examine the prevalence and predictors of poor patient-reported pain, functional limitation, and pain medication use following revision THA. Specifically we examined the: (1) prevalence of moderate–severe pain, moderate–severe activity limitation, nonsteroidal anti-inflammatory drug (NSAID), and narcotic medication use for hip pain and the dependence on walking aids; (2) whether demographic and clinical characteristics such as age, gender (non-modifiable), comorbidity, BMI, depression, and anxiety (modifiable) predict these outcomes.

Methods

Data sources

Patients were included in this prospective cohort study if they underwent a revision THA at the Mayo clinic, Rochester between the years of 1993–2005 and responded to either the 2 or 5 year follow-up pain and function questionnaires. Since 1993, pain and function data have been collected prospectively electronically using validated Mayo Knee and Hip questionnaires as a part of the Mayo Clinic Total Joint Registry. The Mayo hip questionnaire has been validated in comparison to Harris Hip Score [19]; patient-reported Mayo Hip questionnaire scores correlated significantly with physician scores [20]. This prospective registry has collected outcomes including revision and other complications following every arthroplasty since arthroplasty surgeries began in 1969 [21, 22]. The questionnaires are administered to patients by mail, phone call, or during an in-person clinic follow-up visit. The registry captures demographics including age and gender, clinical characteristics such as BMI, implant type, and operative diagnosis. The study was approved by the Mayo Clinic Institutional Review Board.

Additional data were extracted from the institutional electronic databases. These included Deyo–Charlson index score, a validated measure of medical comorbidity [23]; International Classification of Diseases, ninth revision (ICD-9) codes for depression and anxiety; and distance from the medical center (based on zip codes).

Outcomes

The dependent variables evaluated were moderate–severe hip pain, use of NSAIDs for hip pain, use of narcotic medications for hip pain, moderate–severe activity limitation and dependence on walking aids at 2 and 5 years after revision THA. The questions corresponding to each time-point are summarized in Table 1. The 2- and 5-year cohorts may have included patients who responded at both time-points. Among responders, some patients responded at both 2- and 5-year time-points (n=1,191/3,213; 38%), while some responded at 2 years, but not 5 years (n=1,496/3,213; 48%) or at 5 years but not 2 years (n=436/3,213; 14%).

1) Moderate–severe hip pain: reference category, no or slight pain
2) Use of NSAIDs: reference category, no medications or use of oral steroids
3) Use of narcotic medications: reference category, no medications or use of oral steroids

Table 1 Outcomes of interest and questionnaire items corresponding to each outcome

Outcome	Question	Responses
Moderate–severe pain	Do you have pain in the hip in which the joint was replaced? (please mark only one answer)	No pain
		Slight
		Moderate
		Severe
NSAIDs or narcotic use	Do you take medication for pain in your hip?	No
		Yes, NSAIDs
		Yes, narcotics
		Yes, oral steroids
Moderate–severe activity limitations, defined as moderate or severe limitation in ≥3 of the seven activities	How far can you walk before needing to stop and rest? (please mark only one answer)	Unlimited
		4–6 blocks
		1–3 blocks
		Indoors only
		Bed to chair
		Unable to walk
	Can you go up and down the stairs in a normal manner? (please mark only one answer)	Yes
		Yes, using handrail
		One step at a time
		Unable to do up and down stairs
	Can you put on your shoes and socks by yourself? (please mark only one answer)	Yes, with ease
		Yes, with difficulty
		Unable
	Can you pick up an object from the floor? (please mark only one answer)	Yes, with ease
		Yes, with difficulty
		Unable
	How long can you sit in a chair? (please mark only one answer)	Any chair for an hour or more
		A high chair for ½ hour
		Unable to sit for ½ hour
		Unable to sit in any chair
	Can you get in and out of a car? (please mark only one answer)	Yes, with ease
		Yes, with difficulty
		Unable
	When you get out of a chair, can you get to a standing position? (please mark only one answer)	Without using your arms to push up
		Easily by pushing up with your arms
		With difficulty by pushing up with your arms
		Unable to get out of a chair by yourself
Dependence on walking aids, some or complete	Do you use any supports when you walk? (please mark only one answer)	None
		Cane for long walks
		Cane full time
		Crutch
		Two canes
		Two crutches
		Walker
		Unable to walk

4) Moderate–severe activity limitations, defined as moderate or severe limitation in ≥3 of the seven activities walking, stair, shoes/socks, pick up objects from the floor, sitting, getting in/out of the car, rising from chair (reference, all other categories).
5) Dependence on walking aids, some or complete: "no aid" or "cane occasionally"=no dependence; "cane full time"=some dependence; "crutch" "two canes", "two crutches", "walker" or "unable to walk"=complete dependence/unable; reference category, no dependence.

Predictors of interest

The predictors of interest included non-modifiable (age, gender) and modifiable predictors including BMI, comorbidity, depression and anxiety, all assessed at the time of revision THA. These were categorized as follows:

1) Age—categorized as <60, 61–70, 71–80 and >80, categorized as previously [24, 25].
2) Gender—female, male
3) BMI—≤25 (normal), >25–29.9 (overweight); 30–34.9 (mildly obese); 35–39.9 (obese); and ≥40 (morbidly obese), as described previously [26]
4) Comorbidity—measured as a continuous variable, the Deyo–Charlson score [23], the most commonly used comorbidity measure consisting of a weighted scale of 19 comorbidities (including cardiac, pulmonary, renal, hepatic disease, diabetes, cancer, HIV, etc.), expressed as a summative score [27, 28].
5) Depression—an ICD-9 code for depression in patient's medical records (yes/no)
6) Anxiety—an ICD-9 code for anxiety in patient's medical records (yes/no)

Covariates

All regression analyses were adjusted for the following variables in addition to predictors of interest (above):

1) American Society of Anesthesiologists Physical Status (ASA) score, a validated measure of peri- and postoperative outcomes, categorized as class I–II vs. III–IV [29, 30].
2) Operative diagnosis: classified into loosening, wear or osteolysis; dislocation, bone or prosthesis fracture, instability, nonunion; failed prior arthroplasty with components removed or infection.
3) Distance from the medical center: calculated using the zip code data in the year of the survey for US addresses, categorized as <100 miles, 100–500 miles or >500 miles. All non US addresses were classified into >500 miles category. Distance was included as a variable, since Mayo Clinic provides care to both the local population and is a referral center. Patients referred to the Mayo clinic may have more complex underlying diagnoses compared to those seeking care locally.

Statistical analysis

Summary statistics were calculated for sociodemographic and clinical characteristics of cohorts that responded at 2 to 5 years follow-up. Responder characteristics were compared using univariate logistic regression analysis.

We performed univariate and multivariable logistic regression analyses for each of the five outcomes at 2- and 5-year follow-up. These analyses used the generalized estimating equations approach [31] that adjusted the standard errors for the correlation between observations on the same subject due to replacement of both hips and/or multiple operations on the same hip.

All analyses were adjusted for covariates of interest and potential confounders, including age, gender, BMI, comorbidity, distance from the medical center, ASA class, operative diagnosis, depression, and anxiety. Odds ratios (OR) and 95% confidence intervals (CI) are presented. A p value <0.05 was considered significant.

Results

The questionnaire response rate was 58% (2,687/4,628) for the 2-year cohort and 48% (1,627/3,421) for the 5-year cohort. Compared to nonresponders, responders to the questionnaire 2-years postrevision THA were more likely to be older (age 61–70, 71–80 with odds ratios (OR), 1.2 and 1.3, respectively, compared to ≤60 years) and less likely to have BMI 35–39.9 (OR, 0.8), higher Deyo–Charlson index (OR, 0.8 for five-point change) and have an underlying diagnosis of dislocation/fracture (OR, 0.7) or failed arthroplasty with components removed/infection (OR 0.7). At 5 years, responders were less likely to have BMI 35–39.9 (OR, 0.7), ASA class III–IV (OR, 0.8) and have an underlying diagnoses of dislocation/fracture (OR, 0.7) or failed arthroplasty with components removed/infection (OR, 0.8). Nonresponders did not differ from responders with regards to gender or distance from the medical center.

Demographic and clinical characteristics of 2- and 5-year cohorts are described in Table 2. The mean age was 65 years, 54% were women, 29% had normal BMI and 73–75% had osteolysis, wear or osteolysis as the underlying diagnosis. Among those patients who had their primary total hip arthroplasty done at the Mayo Clinic, the mean (SD) duration from primary THA to revision THA was 12.1 (7.7) years (n=1,723). Details for 2- and 5-year cohorts are shown in Table 2.

Table 2 Characteristics of patients with revision THA

	Revision THA	
	2year (*n*=2,687)	5year (*n*=1,627)
Mean age (±SD)	65.7±13.1	64.6±13
Men/women (%)	47%/53%	46%/54%
Age groups *n* (%)		
≤60 years	30%	32%
61–70 years	27%	29%
71–80 years	34%	32%
>80 years	10%	7%
Body mass index (in kg/m^2)		
≤25 (normal)	29%	29%
>25–29.9 (overweight)	38%	40%
30–34.9 (mildly obese)	21%	21%
35–39.9 (obese)	7%	6%
≥40 (morbidly obese)	3%	3%
ASA score		
Class I–II	52%	56%
Class III–IV	48%	43%
Underlying diagnoses		
Loosening/wear or osteolysis	73%	75%
Dislocation, bone or prosthesis fracture, instability, nonunion	17%	15%
Failed prior arthroplasty with components removed or infection	11%	11%
Years since primary total hip arthroplasty[a]	12.5±7.5	12.2±7.3

All numbers were rounded to the nearest digit; therefore, the totals may not exactly add up to 100%

[a] Data were available for patients who had primary THA done at the Mayo Clinic, *n*=987 for 2-year cohort and *n*=624 for 5-year cohort

Moderate–severe hip pain and use of narcotics and NSAIDs for hip pain

Of the revision THAs respondents, 17.6% (451/2,553) and 19.6% (305/1,551) reported moderate–severe pain 2 and 5 years after revision THA, respectively. After multivariable adjustment, the following groups had significantly higher odds of reporting moderate–severe pain 2 years after revision THA: women had 1.3 times odds compared to men; those with BMI 30–34.9 kg/m^2, 1.4 times odds compared to those with BMI ≤25; and those with depression 1.6 times odds compared to those without depression (Table 3). Patients aged 61–70 had an OR of 0.7 of reporting moderate–severe pain compared to those ≤60. Only female gender (OR, 1.5) and age 61–70 (OR, 0.7) were significant predictors of moderate–severe pain at 5-year follow-up.

Of the respondents, 17.3% (417/2,408) and 20.1% (302/1,509) were using NSAIDs at 2-year and 5-year follow-up for pain in their revised THA, respectively. NSAID use 2-years after revision THA was significantly more common in women (OR, 1.4) and in those with BMI of 30–34.9 (OR, 1.4; relative to ≤25) and less common in older subjects aged 71–80 (OR, 0.7; versus ≤60 years; Table 4). Only women were significantly more likely to report using NSAIDs at 5 year follow-up (OR, 1.6).

Of the respondents, 6.6% (160/2,408) and 7.1% (107/1,509 were using narcotic medications at 2-year and 5-year follow-up, for pain in their revised THA, respectively. Narcotic use was significantly less common at 2-year follow-up in older subjects aged 61–70 (OR, 0.5) and 71–80 (OR, 0.4; versus ≤60) and more common in those with depression (OR, 2.4; Table 5). At 5-year follow-up, female gender (OR, 1.8) and age 61–70 years (OR, 0.4) were significantly associated with narcotic medication use.

Comorbidity and anxiety were not associated with moderate–severe pain, NSAID or narcotic medication use 2- or 5-years after revision THA.

Moderate–severe activity limitation and dependence on walking aids

Moderate–severe activity limitation was reported by 54.9% (1,404/2,559) of respondents at 2-years and 56.1% (871/1,552) at 5 years. We found significantly higher odds of moderate–severe activity limitation at 2-year follow-up in the following groups: women (OR, 1.6); patients aged 61–70 (OR, 1.4), 71–80 (OR, 1.9) and ≥80 (OR, 3.5); higher BMI of 30–34.9 (OR, 1.9), 35–39.9 (OR, 2.1), and ≥40 (OR, 2.7); and in those with depression (OR, 1.7; Table 6). At 5-year follow-up, an additional predictor was higher comorbidity (OR, 1.7 for five-point increase in Deyo-

Table 3 Multivariable-adjusted[a] predictors of moderate–severe pain

	Multivariable-adjusted 2-year			Multivariable-adjusted 5-year		
	Odds ratio	95% CI	*p* value	Odds ratio	95% CI	*p* value
Female gender (ref, male)	**1.3**	**1.0, 1.6**	**0.03**	**1.5**	**1.1, 1.9**	**<0.01**
Age (ref, ≤60 years)						
61–70 years	**0.7**	**0.5, 1.0**	**0.03**	**0.7**	**0.5, 1.0**	**0.03**
71–80 years	0.9	0.7, 1.1	0.33	1.0	0.7, 1.4	0.97
>80 years	1.1	0.8, 1.7	0.49	1.0	0.6, 1.7	0.90
BMI (ref, ≤25 kg/m^2)						
>25–29.9 (overweight)	1.1	0.8, 1.4	0.50	1.0	0.7, 1.3	0.87
30–34.9 (mildly obese)	**1.4**	**1.0, 1.9**	**0.03**	1.0	0.7, 1.5	0.88
35–39.9 (obese)	1.5	1.0, 2.3	0.08	0.9	0.5, 1.6	0.70
≥40 (morbidly obese)	1.2	0.7, 2.3	0.49	0.9	0.4, 2.1	0.87
Deyo–Charlson index (five-point change)	1.0	0.7, 1.4	1.00	0.9	0.6, 1.5	0.73
Anxiety (ref, no)	0.5	0.2, 1.0	0.05	0.8	0.3, 1.9	0.56
Depression (ref, no)	**1.6**	**1.0, 2.5**	**0.04**	1.7	1.0, 2.9	0.05

[a] Adjusted for age, gender, BMI, comorbidity, anxiety, depression, ASA class, operative diagnosis, and distance from the medical center

Numbers in *bold* indicate significant odds ratios and *p* values

Charlson) and depression was no longer significantly associated with moderate–severe activity limitation (Table 6).

At 2-year follow-up, 14% (329/2,343) had some dependence and 14.5% (339/2,343) complete dependence on walking aids. At 5-year follow-up, 13.9% (204/1,466) reported some dependence, and 17.2% (252/1,466) complete dependence. Female gender was associated with significantly higher dependence on walking aids at 2- and 5-years (Table 7). Age, 71–80 and ≥80, higher BMI were associated with significantly higher odds of dependence on walking aids at 2- and 5-year follow-up (Table 7).

Anxiety was not associated with moderate–severe functional limitation or use of walking aids 2- or 5-years after revision THA.

Additional covariates significantly associated with these outcomes included the following: (1) greater distance from medical center was associated with higher odds of moderate–severe pain at 5 years, use of NSAIDs at 2 years,

Table 4 Multivariable-adjusted[a] predictors of use of NSAIDs

	Multivariable-adjusted 2-year			Multivariable-adjusted 5-year		
	Odds ratio	95% CI	*p* value	Odds ratio	95% CI	*p* value
Female gender (ref, male)	**1.4**	**1.1, 1.7**	**<0.01**	**1.6**	**1.2, 2.2**	**<0.01**
Age (ref, ≤60 years)						
61–70 years	0.8	0.6, 1.0	0.07	0.8	0.6, 1.1	0.18
71–80 years	**0.7**	**0.5, 0.9**	**0.01**	0.7	0.5, 1.0	0.08
>80 years	0.9	0.6, 1.3	0.47	0.8	0.5, 1.5	0.56
BMI (ref, ≤25 kg/m^2)						
>25–29.9 (overweight)	1.3	1.0, 1.7	0.07	1.1	0.8, 1.5	0.66
30–34.9 (mildly obese)	**1.4**	**1.0, 2.0**	**0.04**	1.0	0.7, 1.5	0.94
35–39.9 (obese)	1.3	0.8, 2.0	0.33	1.2	0.7, 2.2	0.47
≥40 (morbidly obese)	1.7	(0.9, 3.1	0.07	1.1	0.5, 2.5	0.87
Deyo–Charlson index (five-point change)	0.8	0.5, 1.1)	0.17	0.8	0.5, 1.4	0.53
Anxiety (ref, no)	0.7	0.3, 1.4	0.29	0.9	0.4, 2.1	0.72
Depression (ref, no)	1.5	0.9, 2.6	0.12	1.3	0.7, 2.3	0.41

[a] Adjusted for age, gender, BMI, comorbidity, anxiety, depression, ASA class, operative diagnosis, and distance from the medical center

Numbers in *bold* indicate significant odds ratios and *p* values

Table 5 Multivariable-adjusted[a] predictors of use of narcotic medications

	Multivariable-adjusted 2-year			Multivariable-adjusted 5-year		
	Odds ratio	95% CI	*p* value	Odds ratio	95% CI	*p* value
Female gender (ref, male)	1.3	0.9, 1.9	0.11	**1.8**	**1.1, 2.9**	**0.01**
Age (ref, ≤60 years)						
61–70 years	**0.5**	**0.3, 0.7**	**<0.01**	**0.4**	**0.2, 0.7**	**<0.01**
71–80 years	**0.4**	**0.3, 0.7**	**<0.01**	0.7	0.4, 1.1	0.12
>80 years	0.6	0.3, 1.0	0.07	0.6	0.3, 1.4	0.26
BMI (ref, ≤25 kg/m^2)						
>25–29.9 (overweight)	0.9	0.6, 1.4	0.64	1.0	0.6, 1.7	0.97
30–34.9 (mildly obese)	1.2	0.7, 1.9	0.50	1.4	0.7, 2.4	0.32
35–39.9 (obese)	1.1	0.5, 2.2	0.85	0.8	0.3, 2.1	0.62
≥40 (morbidly obese)	1.3	0.6, 3.2	0.52	1.3	0.4, 4.1)	0.68
Deyo–Charlson index (five-point change)	1.1	0.6, 1.8	0.85	1.2	0.6, 2.6	0.59
Anxiety (ref, no)	0.3	<0.1, 1.3	0.11	0.5	<0.1, 2.2	0.33
Depression (ref, no)	**2.4**	**1.2, 4.6**	**0.01**	2.0	0.9, 4.5	0.08

[a] Adjusted for age, gender, BMI, comorbidity, anxiety, depression, ASA class, operative diagnosis, and distance from the medical center

Numbers in *bold* indicate significant odds ratios and *p* values

use of narcotic medications at 2 years, moderate–severe activity limitation at 2 years, and dependence on gait aids at 2 years; (2) an underlying diagnosis of dislocation, fracture, instability or nonunion was associated with higher odds of narcotic use at 5 years, moderate–severe activity limitation at both 2- and 5-years and dependence on gait aids at 2- and 5-years; and (3) higher ASA class was associated with higher odds of moderate–severe activity limitation at both 2- and 5-years and dependence on gait aids at both 2- and 5-years.

Discussion

Our comprehensive study describes patient-reported outcomes, including pain and function and use of pain medications, in one of the largest samples of patients with revision THA to date. In this prospective study of patients who underwent revision THA, we found that at 2- and 5-year follow-up, one-fifth reported moderate–severe pain and half, moderate–severe activity limitation. We found that

Table 6 Multivariable-adjusted[a] predictors of moderate–severe activity limitation after revision THA

	Multivariable-adjusted 2-year			Multivariable-adjusted 5-year		
	Odds ratio	95% CI	*p* value	Odds ratio	95% CI	*p* value
Female gender (ref, male)	**1.6**	**1.4, 2.0**	**<0.01**	**1.8**	**1.4, 2.2**	**<0.01**
Age (ref, ≤60 years)						
61–70 years	**1.4**	**1.1, 1.7**	**<0.01**	1.2	0.9, 1.6	0.29
71–80 years	**1.9**	**1.5, 2.4**	**<0.01**	**2.1**	**1.6, 2.8**	**<0.01**
>80 years	**3.5**	**2.4, 4.9**	**<0.01**	**3.2**	**2.0, 5.3**	**<0.01**
BMI (ref, ≤25 kg/m^2)						
>25–29.9 (overweight)	1.2	1.0, 1.5	0.05	**1.3**	**1.0, 1.8**	**0.04**
30–34.9 (mildly obese)	**1.9**	**1.4, 2.4**	**<0.01**	**1.8**	**1.3, 2.5**	**<0.01**
35–39.9 (obese)	**2.1**	**1.4, 3.1**	**<0.01**	**2.4**	**1.4, 4.0**	**<0.01**
≥40 (morbidly obese)	**2.7**	**1.6, 4.5**	**<0.01**	**3.0**	**1.4, 6.3**	**<0.01**
Deyo–Charlson index (five-point change)	1.3	1.0, 1.8	0.07	**1.7**	**1.1, 2.7**	**0.02**
Anxiety (ref, no)	1.0	0.5, 1.7	0.88	1.0	0.5, 2.2	0.99
Depression (ref, no)	**1.7**	**1.1, 2.6**	**0.03**	1.0	0.6, 1.7	0.98

[a] Adjusted for age, gender, BMI, comorbidity, anxiety, depression, ASA class, operative diagnosis and distance from the medical center

Numbers in *bold* indicate significant odds ratios and *p* values

Table 7 Multivariable-adjusted[a] predictors of dependence on walking/gait aids

	Severity of dependence on walking aids	Multivariable-adjusted 2-year			Multivariable-adjusted 5-year		
		Odds ratio	95% CI	*p* value	Odds ratio	95% CI	*p* value
Female gender (ref, male)	Some dependence	**1.4**	**1.1, 1.8**	**0.01**	1.3	0.9, 1.8	0.13
	Complete dependence/unable	**2.5**	**1.9, 3.3**	**<0.01**	**2.3**	**1.7, 3.2**	**<0.01**
Age (ref, ≤60 years)							
61–70 years	Some dependence	1.0	0.7, 1.5	0.79	1.2	0.7, 1.9	0.50
71–80 years	Some dependence	**1.4**	**1.0, 2.0**	**0.03**	**2.5**	**1.6, 3.8**	**<0.01**
>80 years	Some dependence	**2.9**	**1.9, 4.5**	**<0.01**	**3.5**	**1.8, 6.8**	**<0.01**
61–70 years	Complete dependence/unable	1.1	0.8, 1.7	0.57	1.0	0.6, 1.6	0.95
71–80 years	Complete dependence/unable	**2.1**	**1.5, 3.0**	**<0.01**	**2.6**	**1.7, 3.9**	**<0.01**
>80 years	Complete dependence/unable	**4.8**	**3.1, 7.5**	**<0.01**	**6.5**	**3.7, 11.3**	**<0.01**
BMI (ref, ≤25 kg/m^2)							
>25–29.9 (overweight)	Some dependence	1.2	0.9, 1.7	0.23	1.1	0.8, 1.7	0.53
30–34.9 (mildly obese)	Some dependence	**1.5**	**1.1, 2.2**	**0.02**	1.4	0.9, 2.3	0.15
35–39.9 (obese)	Some dependence	1.7	1.0, 2.8	0.05	1.9	1.0, 3.8	0.06
≥40 (morbidly obese)	Some dependence	1.7	0.8, 3.4	0.14	2.5	1.0, 6.2	0.05
>25–29.9 (overweight)	Complete dependence/unable	0.9	0.7, 1.3	0.75	1.0	0.7, 1.5	0.85
30–34.9 (mildly obese)	Complete dependence/unable	1.1	0.8, 1.6	0.57	1.2	0.7, 1.9	0.48
35–39.9 (obese)	Complete dependence/unable	1.4	0.9, 2.4	0.17	1.6	0.9, 3.1	0.13
≥40 (morbidly obese)	Complete dependence/unable	**2.0**	**1.0, 3.8**	**0.04**	**2.7**	**1.2, 6.2**	**0.02**
Deyo–Charlson index (five-point increase)	Some dependence	1.2	0.8, 1.7	0.46	1.2	0.7, 2.2	0.51
	Complete dependence/unable	1.4	0.9, 2.0	0.10	1.5	0.9, 2.6	0.10
Anxiety (ref, no)	Some dependence	1.1	0.5, 2.5	0.78	0.3	<0.1, 1.4	0.12
	Complete dependence/unable	0.9	0.4, 2.0	0.87	1.2	0.5, 2.9	0.62
Depression (ref, no)	Some dependence	0.9	0.5, 1.7	0.73	1.0	0.5, 2.2	0.99
	Complete dependence/unable	1.3	0.7, 2.2	0.44	1.2	0.6, 2.3	0.61

[a] Adjusted for age, gender, BMI, comorbidity, anxiety, depression, ASA class, operative diagnosis, and distance from the medical center

Numbers in *bold* indicate significant odds ratios and *p* values

one-fifth used NSAIDs and 7% narcotic medications. Fourteen percent patients reported some dependence on walking aids and 14–17%, complete dependence. We found that female gender, higher BMI, and age were independently significantly associated with each of the following outcomes at 2-years: higher odds of moderate–severe pain, use of NSAIDs, moderate–severe activity limitation and dependence on walking aids. Similar associations were noted for female gender, higher BMI and age with pain, function, and pain medication use, except lack of few associations for NSAID use. Additionally, depression was significantly associated with moderate–severe pain, use of narcotic medications and moderate–severe activity limitation at 2-year follow-up.

Study strengths Our study examined a large cohort of revision THAs (sample size~10 times larger than all previous studies), performed multivariable adjustment for important variables, followed patients up to 5-years, and included patient-relevant clinically meaningful outcomes. We provide estimates and predictors of not only pain and activity limitations, but also for the use of NSAIDs and narcotic medications and dependence on walking aids.

Study limitations Our study has several limitations. A major limitation of our study was our inability to control for preoperative pain and limitation, which may be important predictors of postoperative outcomes and may have led to residual confounding. Our study was not designed to assess the impact of surgical technique or factors on outcomes, which would also lead to residual confounding. Nonresponse bias and single-center study limit the generalizability of study findings. The 2-year response rate was similar to the mean 60% response rate reported in a review of published mailed surveys, but the 5-year rates were low at 48% [32]. The 5-year estimates have higher potential to be biased. However, there are no national registries in the USA except specific implant registries [33] and due to a high success of arthroplasty surgery, large sample sizes, and long follow-up are needed to understand the epidemiology and predictors of pain and activity limitation. Our study only provides short intermediate-term follow-up. Prospective multicenter studies of longer follow-up are needed to improve our understanding of outcomes. Limited validation data have been published for the Mayo Hip questionnaire, which has been validated against the Harris Hip Score [19]. The Mayo Hip and Mayo Knee questionnaires have been consistently used in the vast majority of studies for both knee and hip arthroplasty from the Mayo Clinic in the last 40 years [19, 20, 22, 34–37]. The Mayo Hip instrument has not been rigorously validated against Western Ontario and McMaster Osteoarthritis Index (WOMAC) and Short Form-36, which were invented more recently and has not undergone additional validation. Our study was limited in the ability to adjust functional limitation for use of walking aids, since both data were collected at the same follow-up time-points. However, it is important to examine dependence on walking aids as an independent outcome, as a measure of activity independence/limitation. Future studies should examine this relationship and examine if our findings can be verified in other patient cohorts. Inclusion of preoperative variables, important predictors of these outcomes, would have made these analyses more robust. ICD-codes were used to identify presence of anxiety and depression, however both underdiagnosis and inaccuracy may have limited us in truly identifying the presence of these conditions. We carefully considered but could not identify significant changes in surgical technique over time based on patient characteristics. However, it is possible that some surgical technique may have influenced success rates and led to confounding bias.

What is known? In a Norwegian study of 531 patients with revision THA, older age and in some cases, female gender, were associated with lower improvement in pain and walking scores [13]. In another study of 235 patients with revision THA, male gender, age 60–70 and lower Charnley class were associated with better WOMAC pain and function 1- and 2-years after surgery, while BMI was not associated with either outcome [11]. These analyses were additionally adjusted for preoperative pain and function, indication for revision, duration of surgery, other surgical and component factors, and prior revision. Lubbeke et al. examined 204 patients with revision THAs and found that obese patients with BMI $\geq$30 kg/m^2 had significantly lower functional and pain scores on Harris Hip scale at 5-year follow-up, adjusted for age, sex, preoperative function and pain, ASA score, and Charnley classification grade [14]. Davis et al. studied 126 THAs and found that after adjusting for preoperative scores, age, gender, SF-36 scores, comorbidities, number of revisions, bilateral joint replacement and the severity of the revision, preoperative pain and higher comorbidity were significantly associated with WOMAC pain 2-years after revision THA, while none of the factors examined predicted WOMAC function at 2 years [12]. Two retrospective studies from Canada consisting of 41 [16] and 24 revision THAs [15] with mean follow-up ranging 2.8–3.4 years, showed that female gender and older age were associated with worse functional outcomes after multivariate adjustment for gender, age, time to revision, morcelized allograft, use of screws for acetabular fixation, femoral revision [16], whereas neither were associated with pain or function after adjustment for diagnosis of hip disease, date of arthroplasty, operative details, cement use, use of screws [15]. Thus, evidence from previous studies suggests that BMI, age, gender, and comorbidity may be associated with poorer pain and function outcome after revision THA.

Depression and outcomes The association of depression with higher odds of moderate to severe pain, narcotic use and moderate–severe activity limitation 2-years post revision THA is a novel addition to the literature. To our knowledge, none of the previous studies have examined the effect of psychological distress on patient-reported outcomes after revision THA. Psychological distress is associated with poorer pain and function outcomes following primary TKA [17] and after spinal fusion surgery [38]. Our study extends this finding to patients undergoing revision THA. The reason why depression may be associated with these poorer outcomes is due to heightened pain sensitivity, poor participation in rehabilitation by depressed patients and/or low expectations of pain relief and functional recovery from revision THA, which impacts arthroplasty outcomes [39]. Depression is a modifiable factor. It is possible that preoperative screening and treatment of depression in revision THA patients may improve pain and functional outcomes.

Studies in nonarthroplasty populations have reported an association of depression with higher analgesic use following surgery [40–42]. Our study found an association of depression with higher narcotic use 2-years after revision THA, which extends this finding to revision THA cohort.

Similarly, the lack of association of anxiety with pain and function outcomes in revision THA patients is a new finding. Anxiety has been reported to be associated with pain outcomes at 1 year [43], but not at 5 years [18] after knee arthroplasty; trait anxiety was associated with pain 6 months after primary hip arthroplasty, but not preoperative state anxiety [44]. These studies differ in the patient populations (revision THA vs. primary knee or hip arthroplasty) and in case identification (ICD-9 code vs. State-trait anxiety index). It is possible that we may have underdiagnosed anxiety, since we used ICD-9 codes.

Gender and outcomes Female gender was associated with higher odds of moderate to severe pain and use of NSAIDs and narcotic medications at 2- and 5-years postrevision THA in this study. Previous studies have reported more pain in female patients at 1–2 year follow-up [11, 13], confirmed by our study in a larger cohort and extended to a 5-year follow-up. Worse pain outcomes in women may be due to differences in perception of pain between genders and/or higher preoperative pain severity in women [45] or a difference in their willingness to report their pain severity accurately.

To our knowledge, this study is the first to provide detailed data regarding the use and predictors of NSAIDs and narcotic medications for hip pain postrevision THA. One previous study in revision THA patients reported pain medication use—5% were taking narcotic medications and 56% NSAIDs at 2 years [12]. Our study found similar prevalence of narcotic use (7%), but a lower prevalence of NSAID use (17–20%), despite a similar age of the two cohorts. Higher prevalence of analgesic use in women vs. men has been reported in the US [46] and Swedish National cohorts [47].

The association of female gender with more functional limitation reported in two prospective studies [11, 13] and one retrospective study [16] was confirmed in our study. A higher dependence of women on walking aids adds to the current knowledge. Again, higher postoperative functional limitation in women versus men may be due to higher preoperative limitation [45], higher severity of arthritis of other lower extremity joints including knee and contralateral hip joint [48] and/or more pain severity interfering with their physical recovery.

Age and outcomes In our study, older age was associated with lower odds of moderate to severe pain, NSAID, and narcotic use and of higher odds of moderate–severe activity limitation and dependence on walking aids. Previous studies have reported less pain [11, 13] and more functional limitation in older patients postrevision THA [11, 13, 16], which were confirmed in our study. The higher postoperative functional limitation in more elderly is likely related to greater severity of other comorbidity (back problems, vision, and balance problems, etc.) not captured by the Deyo–Charlson index and higher risk of arthritis in other lower extremity joints with aging [49]. Better pain outcomes in the more elderly compared to younger patients may be due to higher pain tolerance, lower physical demands for sports-related activities, and lower prevalence of subclinical anxiety and depression (not captured by ICD-codes).

Our finding of less frequent use of NSAIDs and narcotic medications in patients aged 61–70 and 71–80 (relative to <60), who also report less pain, adds to the literature. This observation is similar to a Swedish study that found lower analgesic use in 45–64 and 65–74 year old subjects compared to 18–44, after adjustment for other significant predictors [47].

BMI and outcomes One previous study reported that BMI >30 was associated with worse pain and worse function compared to nonobese patients at 5 years [14]. Another study reported no significant association of obesity with pain or function at 2-year follow-up [11]. We found that odds of activity limitation were increased in patients with BMI categories above 30 at both 2- and 5-years, and that dependence on walking aids increased only in patients with BMI ≥40. Many differences exist between our study versus the Lubbeke [14] and Biring study [11]: (1) average age of cohorts was 68 vs. 69 vs. 65 years; (2) BMI categories differed—five categories in our study vs. four categories vs. continuous; (3) follow-up duration: 2- and 5-years in our study vs. 5 years vs. 1- and 2-years; and (4) confounders adjusted in the studies differed somewhat. Thus, higher BMI seems to predict worse pain and function in short intermediate-term follow-up of patients with revision THA. This association may be due to higher postoperative complication rates [50], especially in obese women [3], lower efficiency in achieving physical improvements during inpatient rehabilitation [51], higher likelihood of discharge to skilled nursing facility [50], and possibly altered biomechanics related to body mass.

Comorbidity and outcomes Comorbidity was not associated with any outcome at 2-years and only with activity limitation at 5-years. This is in contrast to Biring et al.'s study that reported this association at 1- and 2-year follow-up [11], but in agreement with Davis et al. that reported lack of this association at 2-years [12]. The difference may be due to differences in the measure of comorbidity (Deyo–Charlson vs. Charnley vs. not specified), its categorization for the analyses (continuous vs. categorical vs. categorical) or in types of covariate used for multivariable adjustment. Higher postoperative complication rates and nonhomebound discharges as noted in patients with higher comorbidity, a national study of THA [52], peripheral neuropathy, and peripheral vascular disease that accompany common diseases such as diabetes and heart disease and reduced ability to perform rehabilitation with higher comorbidity may underlie these differences in outcomes following revision THA.

In conclusion, in this large study of revision THAs, we found that moderate–severe pain, moderate–severe activity limitation and dependence on walking aids were common at 2- and 5-year follow-up. Female gender and higher BMI were associated with poorer pain and function outcomes at 2- and 5-years. Older age was associated with less pain, but more functional limitation and greater dependence on walking aids. Depression was associated with poorer pain and function outcomes and higher likelihood of narcotic medication use at 2-year follow-up. Our study identifies many modifiable factors that can be targeted for improving outcomes after revision THA.

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