# Dependence on Walking Aids at 2- And 5-Years after Total Hip Arthroplasty is Associated with Pain and Mobility Limitation

## Singh AJ[1,2,3*] and Lewallen DG[3]

[1]Medicine Service and Centre for Surgical Medical Acute Care Research and Transitions (C-SMART), Birmingham VA Medical Centre, Birmingham, USA

[2]Department of Medicine at School of Medicine, and Division of Epidemiology at School of Public Health, University of Alabama, Birmingham, USA

[3]Department of Orthopedic Surgery, Mayo Clinic College of Medicine, Rochester, MN, USA

*****Corresponding author:** Singh AJ, University of Alabama, Faculty Office Tower 805B, 510 20th Street S, Birmingham, USA, Tel: 205-996-5885; E-mail: Jasvinder.md@gmail.com

## Abstract

**Objective:** To assess the association of dependence on walking aids at 2- and 5-years after total hip arthroplasty (THA) with pain and function outcomes.

**Methods:** We used the Mayo Clinic Total Joint Registry to study patients who underwent primary or revision THA between 1993-2005 and completed a 2-year or 5-year Mayo Hip Survey consisting of pain and function assessments. Multivariable-adjusted logistic regression assessed the associations, adjusting for clinical/demographic variables and preoperative pain and function.

**Results:** Primary THA cohort had 5,707 patients at 2-year and 3,289 at 5-years; revision THA included 2,667 patients at 2-year and 1,627 patients at 5-years. Compared to patients with no dependence on walking aids, patients with some dependence or complete dependence on walking aids, respectively, had significantly higher odds (95% confidence interval) of: (1) moderate-severe pain post-primary THA at 2-years: 3.40 (2.06, 5.62) and 4.79 (2.88, 7.97); (2) moderate-severe pain post-primary THA at 5-years: 3.92 (2.21, 6.95) and 3.47 (1.97, 6.11); (3) moderate-severe pain post-revision THA at 2-years, 4.67 (2.76, 7.91) and 2.95 (1.65, 5.27); (4) moderate-severe pain post-revision THA at 5-years: 3.95 (1.86, 8.38) and 5.16 (2.59, 10.3); (5) moderate-severe mobility limitation post-primary THA at 2-years: 10.7 (6.78, 17.0) and 14.2 (8.32, 24.3); (6) moderate-severe mobility limitation post-primary THA at 5-years: 13.2 (7.34, 23.7) and 21.4 (10.6, 43.2); (7) moderate-severe mobility limitation post-revision THA at 2-years: 4.90 (2.87, 8.37) and 8.26 (4.12, 16.6); (8) moderate-severe mobility limitation post-revision THA at 5-years: 5.12 (2.32, 11.3) and 10.1 (4.53, 22.7), respectively.

**Conclusions:** Post-THA dependence on walking aids at 2- and 5-years was associated with worse pain and function outcomes post-THA.

**Keywords:** Total hip arthroplasty; Hip replacement; Dependence; Walking aids; Mobility; Frailty; Primary THA; Revision THA; Pain; Mobility limitation

## Introduction

Total Hip Arthroplasty (THA) is second most common joint arthroplasty performed in the U.S. The annual estimated volume for primary THA was 438,000 in 2009 based on the National Inpatient Sample (NIS), a U.S representative sample [1]. The rates of THA doubled from 1991 to 2006 in the U.K [2]. A similar increase in THA rates has been reported in Denmark, Sweden and Norway [3]. THA is associated with significant improvements in function, HRQOL and pain [4-6]. Pain and function are important patient-reported outcomes (PROs) after THA. There is a lot of interest in understanding predictors of pain and function outcomes post-THA [6-8]. Pre- and post-THA dependence on walking aids, as a marker of decreased mobility [9] and frailty [10], may be associated with these important PROs.

In previous studies, preoperative use of walking aids by THA patients was associated with a 40% higher odds of hospital stay >3 days in 712 patients [11], a longer hospital stay in 112 patients aged 75 years or older [12], and higher mortality after THA/THA in 1,922 patients 75 years or older [13]. To our knowledge, studies have not examined whether the long-term post-THA use of walking aids [not just immediate post-operative use during rehabilitation is associated with poorer patient-reported outcomes (PROs) after THA. Therefore, study of dependence on walking aids, as a surrogate measure for poor outcomes, is of interest.

One expects post-operative dependence on walking aids and functional limitation to be strongly correlated. Most

patients who use walking aids post-arthroplasty have significant pre-operative functional limitation (the underlying reason for the long-term use of walking aids). It is not known, if this association would still hold after accounting for pre-operative functional limitation. Research studies include collection of patient-reported functional limitation and pain assessments, but routine collection of these outcomes is expensive and impractical in a busy practice setting. Currently, most practices in the U.S. do not collect pre- and post-arthroplasty patient-reported outcomes measures [14]. It is likely that time and resources are two major barriers to repeated data collection in a real-world practice setting. In contrast to multi-item pain/function assessments, dependence on walking aids can be easily observed during clinic visit and/or queried as a simple, single item measure, either patient-reported or observed by the office staff checking the patient in. Single-item measures are more practical than long questionnaires and may sometimes capture the domain of interest just as well as long questionnaires [15]. Thus, they may sometimes serve as measures or surrogate measures of important clinical outcomes.

It is also not known whether dependence on walking aids post-THA is associated with post-THA pain in the index hip joint. THA is associated with pain relief in most patients, but persistent post-THA pain is reported by 11% of the THA recipients 5-years post-THA [6]. The recognition of factors associated with refractory post-THA pain can improve our understanding of this problem and its management in the future. It is not known whether dependence on walking aids might be a surrogate for worse pain and function outcomes post-THA. While its association with functional limitation is intuitive, its association with post-THA pain has not been established. To our knowledge, no previous study has examined if greater dependence on walking aids predicts worse pain and function post-THA. Therefore, our objective was to assess whether long-term post-arthroplasty dependence on walking aids is associated with PROs, pain and mobility limitation, at 2- and 5-years after primary and revision THA and whether the degree of dependence on walking aids, some vs. complete dependence, is associated with these PROs.

## Methods

### Data source and study cohort

The study was conducted using data from the Mayo Clinic Total Joint registry, an institutional registry that collects prospective data on all patients undergoing joint arthroplasty at the Mayo Clinic, Rochester, MN. Patients were selected if they had undergone primary or revision THA between 1993 and 2005 at our institution, were alive at follow-up visit and had responded to Mayo Hip survey, either at 2-year or 5-year after primary or revision THA. The Mayo Hip Survey is a validated outcome instrument that has construct validity and reliability [16,17] and has been used for >3 decades at the Mayo Clinic; responsiveness has not been demonstrated. The survey is mailed to the patients or administered in the clinic during follow-up visits, as a part of regular clinical follow-up.

For patients who failed to respond to mailed survey and/or return for clinic follow-up, trained Joint Registry staff administered the questionnaire on the telephone. The Institutional review board at the Mayo Clinic approved this study and waived the need for informed consent from patients for this database study. Methods and results are described as recommended in the STrengthening of Reporting in OBservational studies in Epidemiology [STROBE] statement [18].

### Exposure of interest

Post-THA dependence on walking aids, a marker of frailty, was the exposure of interest. Long-term post-THA dependence on walking aids at the time of 2- or 5-year post-THA surveys was assessed. Responses were categorized as follows: "none" or "cane for long walks"= no dependence; "cane full time"= some dependence; "crutch" "two canes", "two crutches", "walker" or "unable to walk"= complete dependence/unable, as previously [7,8,19]. Some vs. complete dependence on walking aids allowed us to examine dose-relationships with PROs.

### Outcome

Two PROs, pain and mobility limitation at 2- or 5-year follow-up, were the main outcomes of interest. Pain was assessed with the question "How much pain do you have in your operated hip?" with responses being 'none', 'mild', 'moderate', 'severe'. Moderate and severe pain categories were combined into moderate-severe pain, an a priori decision based on an orthopedic surgeon's recommendation (D.G.L.) that moderate-severe THA pain is an undesirable outcome, as in previous studies [6,8]. Limitations in walking, climbing stairs, sitting, rising from chair were categorized into no, mild, moderate or severe limitation for each activity. Limitations in putting on shoes/socks, picking up objects from the floor, getting in/out of the car into none, moderate or severe limitation, due to no response category corresponding to mild limitation. We defined overall moderate-severe mobility limitation as moderate or severe limitation in ≥3 activities, as previously [7, 8].

### Covariates and potential confounders

We included several important demographic and patient characteristics at the time of THA, included due to known or potential association with PROs after THA. Age was categorized into ≤60, 61-70, 71-80 and >80, as previously [20,21]. BMI was categorized into ≤25, 25.1-29.9, 30-34.9, 35-39.9 and ≥40 [22]. Deyo-Charlson score, a validated comorbidity measure [23], consisting of a weighted scale of 17 comorbidities (including cardiac, pulmonary, renal, hepatic disease, diabetes, cancer, HIV etc.), was expressed as a summative score [24,25]; it was treated as a continuous variable. Depression and anxiety were assessed by the presence or absence of the respective International Classification of Diseases- ninth revision (ICD-9) at the time of THA, obtained from patient's entire medical record, as

previously [6,8]. Income was categorized as $35K, >$35K–$45K or >$45, determined based on zip code and the median household income for geographical area using the census data for the respective year of survey income [26]. Distance to medical center was categorized as 0–100 miles, >100–500 miles, >500 miles [7,19]; operative diagnosis as osteoarthritis, rheumatoid/inflammatory arthritis, or other (avascular necrosis, fracture etc.) [6,7]; and American Society of Anesthesiologists (ASA) class, a validated measure of peri- and post-operative outcomes, as class I–II vs III–IV [27,28], as previously [29,30]. Distance from the medical center was included, since Mayo Clinic provides THA to local residents, but also a serves as a referral center for patients traveling from far, who may have different disease severity and expectations, and both can impact pain and function outcomes [31].

## Bias and sample size

We tried to minimize confounding bias by including factors either previously known or suspected to be associated with PRO outcomes, but recognize that residual confounding is a limitation of the cohort study design. We did not perform formal sample size calculations and since our goal was to have a large enough sample to study the question of interest, we chose the study period 1993-2005 that provided a large sample size.

## Statistical analyses

We used t-test for continuous and chi-squared tests for categorical baseline variables. Responder and non-responder characteristics were compared using logistic regression analyses. Given the large sample size, we decided a priori not to impute missing data and to treat it as missing. We used multivariable-adjusted multinomial logistic regression analyses to assess the association of post-THA dependence on walking aids (some vs. none; complete/unable vs. none) at 2- and 5-years post-primary THA and post-revision THA. Analyses were adjusted for important covariates and potential confounders in stepwise hierarchical models that included important covariates and potential confounders: age, sex, Deyo-Charlson index (Model 1); model 1 + anxiety and depression (Model 2); model 2 + BMI, income, distance to medical center, operative diagnosis and ASA class (Model 3); Model 2 + preoperative pain (Model 4); Model 3 + preoperative pain (Model 5); Model 3 + preoperative pain + preoperative mobility limitation (Model 6). We used a Generalized Estimating Equations (GEE) approach to adjust for the correlation between observations on the same subject due to replacement of both hips or multiple surgeries.

# Results

## Cohort characteristics

5,707 patients with primary THA provided 2-year and 3,289 provided 5-year pain and function outcomes data. Mean age was 65 years, 51-54% were female, 30% were 60 year or younger, 24% had BMI <25 kg/m2 and ASA class was III or IV in

38% of patients (Table 1). 2,667 patients with revision THA provided 2-year and 1,627 patients, 5-year data. Characteristics were similar to primary THA cohort (Table 1).

**Table 1:** Demographic features of primary and revision Total Hip Arthroplasty (THA) cohorts.

| | Primary THA | | Revision THA | |
|---|---|---|---|---|
| | **2-year** | **5-year** | **2-year** | **5-year** |
| | **(N=5,707)** | **(N=3,289)** | **(N=2,687)** | **(N=1,627)** |
| **Mean Age (±SD)** | 65.0 ± 13.3 | 64.7 ± 12.9 | 65.7 ± 13.1 | 64.6 ± 13 |
| **Men/ Women (%)** | 49%/51% | 47%/53% | 47%/53% | 46%/54% |
| **Age groups n (%)** | | | | |
| ≤60 yrs | 30% | 30% | 30% | 32% |
| >60-70 yrs | 31% | 32% | 27% | 29% |
| >70-80 yrs | 30% | 31% | 34% | 32% |
| >80 yrs | 9% | 6% | 10% | 7% |
| **Body Mass index (in kg/m2)** | | | | |
| ≤24.9 | 24% | 24% | 29% | 29% |
| 25-29.9 | 39% | 40% | 38% | 40% |
| 30-34.9 | 24% | 23% | 21% | 21% |
| 35-39.9 | 8% | 8% | 7% | 6% |
| ≥40 | 4% | 4% | 3% | 3% |
| **American Society of Anesthesiologists (ASA)** | | | | |
| Class I-II | 62% | 64% | 52% | 56% |
| Class III-IV | 38% | 36% | 48% | 43% |
| SD, standard deviation | | | | |

## Non-response Bias

The survey response rate was 62.3% (5,707/9,154) 2-years after primary THA and 52.7% (3,289/6,243) 5-years after primary THA. The survey response rate was 58% (2,687/4,628) for the 2-year and 48% (1,627/3,421) for the 5-year revision THA cohort. Of the 9,484 primary THAs, 9,154 were alive at 2-year follow-up (3.4% died). Of the 4,829 revision THAs, 4,628 were alive (4.1% died) and eligible for 2-year follow-up.

Compared to non-responders, survey responders at 2-years post-primary THA were more likely to be older (age 61-70, 71-80 and >80 with odds ratios (OR) =1.4, 1.3 and 1.3, compared to ≤ 60 years) and less likely to have BMI ≥ 40 (OR = 0.7, compared to <25), ASA class IIIIV (OR = 0.9, compared to class I). At 5-years, responders were more likely to be older (age 61- 70, 71-80 with OR = 1.4 and 1.4) and have BMI 25-29.9 (OR = 1.2).

Compared to non-responders, responders to the questionnaire 2-years post-revision THA were more likely to be

older (age 61–70, 71–80 with OR = 1.2 and 1.3, respectively) 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).

## Unadjusted rates of post-THA dependence on walking aids/supports

The rates of some dependence on walking aids post-THA ranged from 10.8% for the 2-year to 12.8% for the 5-year primary THA cohorts (Table 2). Another 5-7% patients of the 2- and 5-year cohorts reported complete dependence on walking aids post-THA. Some dependence and complete dependence rates in revision THA cohorts were higher: 28.7% and 14.6% at 2-years; and 30.9% and 17.2% at 5-years, respectively.

**Table 2:** Unadjusted rates of dependence on walking aids for the 2-year and 5-year THA cohorts, *Missing data: Primary THA: 202 from the 2-year and 131 from the 5-year, Revision THA: 73 from the 2-year and 49 from the 5-year.

|  | Primary THA* | | Revision THA* | |
|---|---|---|---|---|
|  | 2-yr cohort | 5-yr cohort | 2-yr cohort | 5-yr cohort |
|  | (N=5,707) | (N=3,289) | (N=2,687) | (N=1,627) |

| Walking aids |  |  |  |  |
|---|---|---|---|---|
| No dependence | 4911 (89.2%) | 2738 (83.2%) | 1844 (68.6%) | 1075 (66.1%) |
| Some dependence | 308 (5.6%) | 194 (5.9%) | 379 (14.1%) | 223 (13.7%) |
| Complete dependence or unable to walk | 286 (5.2%) | 226 (6.9%) | 391 (14.6%) | 280 (17.2%) |

## Post-THA dependence on walking aids and pain and function outcomes in primary THA cohorts

Unadjusted analyses showed that post-THA dependence on walking aids was associated significantly with higher odds of moderate-severe pain 2- and 5-years after primary THA (Table 3). In hierarchical multivariable-adjusted models that additionally adjusted for other covariates including preoperative pain and function, no significant attenuation in magnitude or the strength of association was noted, compared to univariate models (Table 3). For example, the odds of moderate-severe pain in the full multivariable-adjusted model (model 6) at 2-years post-THA were 3.40 (2.06, 5.62) for some dependence and 4.79 (2.88, 7.97) for complete dependence on walking aids (Table 4).

**Table 3:** Dependence on walking aids and moderate-severe pain 2- and 5-years after primary THA.

|  | Primary THA | | Revision THA | |
|---|---|---|---|---|
|  | 2-year post-THA | 5-year post-THA | 2-year post-THA | 5-year post-THA |
|  | Odds ratio (95% CI) | Odds ratio (95% CI) | Odds ratio (95% CI) | Odds ratio (95% CI) |
| Unadjusted |  |  |  |  |
| **Some dependence** | 4.48 (3.34, 6.02)[*] | 3.90 (2.73, 5.58)[*] | 3.16 (2.41, 4.14)[*] | 2.25 (1.59, 3.19)[*] |
| **Complete dependence** | 3.87 (2.80, 5.34)[*] | 3.06 (2.17, 4.34)[*] | 3.33 (2.55, 4.33)[*] | 3.13 (2.29, 4.29)[*] |
| Model 1: Age, sex, Deyo-Charlson |  |  |  |  |
| **Some dependence** | 4.78 (3.49, 6.55)[*] | 4.84 (3.32, 7.07)[*] | 3.35 (2.54, 4.42)[*] | 2.43 (1.70, 3.45)[*] |
| **Complete dependence** | 4.07 (2.86, 5.80)[*] | 3.81 (2.62, 5.55)[*] | 3.55 (2.69, 4.70)[*] | 3.37 (2.40, 4.75)[*] |
| Model 2: Age, sex, Deyo-Charlson, anxiety, depression |  |  |  |  |
| **Some dependence** | 4.73 (3.44, 6.49)[*] | 4.83 (3.31, 7.05)[*] | 3.39 (2.57, 4.47)[*] | 2.42 (1.70, 3.45)[*] |
| **Complete dependence** | 3.92 (2.75, 5.58)[*] | 3.78 (2.59, 5.51)[*] | 2.55 (2.68, 4.70)[*] | 3.39 (2.41, 4.78)[*] |
| Model 3: Model 2 + BMI, income, distance to medical center, operative diagnosis, ASA class |  |  |  |  |
| **Some dependence** | 4.45 (3.11, 6.36)[*] | 4.41 (2.86, 6.80)[*] | 3.89 (2.79, 5.43)[*] | 2.78 (1.75, 4.39)[*] |
| **Complete dependence** | 4.04 (2.74, 5.98)[*] | 2.93 (1.86, 4.61)[*] | 4.05 (2.89, 5.66)[*] | 3.82 (2.49, 5.85)[*] |

| | | | | |
|---|---|---|---|---|
| Model 4: Model 2 + preoperative pain | | | | |
| **Some dependence** | 3.85 (2.49, 5.95) | 4.80 (2.96, 7.78) | 4.03 (2.63, 6.20)* | 2.52 (1.44, 4.40)* |
| **Complete dependence** | 4.54 (2.88, 7.13)* | 4.45 (2.76, 7.15)* | 2.81 (1.74, 4.53)* | 3.30 (1.88, 5.78)* |
| Model 5: Model 3 + preoperative pain | | | | |
| **Some dependence** | 3.43 (2.09, 5.62)† | 3.89 (2.21, 6.84)† | 4.90 (2.95, 8.13)* | 3.82 (1.78, 8.17)* |
| **Complete dependence** | 4.83 (2.92, 7.96)† | 3.38 (1.93, 5.92)* | 2.85 (1.62, 5.02)* | 5.41 (2.69, 9.39)* |
| Model 6: Model 3 + preoperative pain + preoperative mobility limitation | | | | |
| **Some dependence** | 3.40 (2.06, 5.62)† | 3.92 (2.21, 6.95)* | 4.67 (2.76, 7.91)* | 3.95 (1.86, 8.38)* |
| **Complete dependence** | 4.79 (2.88, 7.97)† | 3.47 (1.97, 6.11)* | 2.95 (1.65, 5.27)* | 5.16 (2.59, 10.3)* |
| *p-value <0.001 | | | | |
| † p-value ≤0.01 | | | | |
| CI, confidence interval; BMI, body mass index; ASA, American Society of Anesthesiologists | | | | |

**Table 4:** Dependence on walking aids and moderate-severe mobility limitation 2- and 5-years after primary THA.

| | Primary THA | | Revision THA | |
|---|---|---|---|---|
| | 2-year post-THA | 5-year post-THA | 2-year post-THA | 5-year post-THA |
| | Odds ratio (95% CI) | Odds ratio (95% CI) | Odds ratio (95% CI) | Odds ratio (95% CI) |
| Unadjusted | | | | |
| **Some dependence** | 15.2 (11.1, 20.8)* | 14.8 (9.8, 23.3)* | 6.89 (5.13, 9.24)* | 7.30 (4.94, 10.8)* |
| **Complete dependence** | 24.5 (16.8, 35.6)* | 26.8 (16.8, 42.8)* | 19.3 (12.8, 29.0)* | 16.9 (10.6, 26.9)* |
| Model 1: Age, sex, Deyo-Charlson | | | | |
| **Some dependence** | 12.5 (9.05, 17.2)* | 12.6 (8.27, 19.1)* | 6.46 (4.79, 8.71)* | 6.82 (4.59, 10.1)* |
| **Complete dependence** | 19.7 (13.5, 28.8)* | 22.3 (13.9, 35.8)* | 16.5 (10.9, 24.9)* | 14.6 (9.14, 23.3)* |
| Model 2: Age, sex, Deyo-Charlson, anxiety, depression | | | | |
| **Some dependence** | 12.4 (8.96, 17.1)* | 12.5 (8.19, 19.2)* | 6.50 (4.82, 8.77)* | 6.81 (4.59, 10.1)* |
| **Complete dependence** | 19.3 (13.2, 28.2)* | 21.9(13.6, 35.2)* | 16.5 (10.9, 24.9)* | 14.6 (9.18, 23.3)* |
| Model 3: Model 2 + BMI, income, distance to medical center, operative diagnosis, ASA class | | | | |
| **Some dependence** | 9.8 (6.85, 13.9)* | 11.4 (6.92, 18.9)* | 5.34 (3.78, 7.54)* | 6.30 (3.91, 10.1)* |
| **Complete dependence** | 15.1 (9.90, 22.9)* | 23.2 (13.0, 41.5)* | 13.9 (8.65, 22.3)* | 14.1 (7.88, 25.2)* |
| Model 4: Model 2 + preoperative pain | | | | |
| **Some dependence** | 13.3 (8.68, 20.4) † | 13.3 (8.02, 22.0)† | 5.36 (3.37, 8.53)* | 5.28 (2.87, 9.71)* |
| **Complete dependence** | 17.8 (10.9, 29.0)* | 21.6 (12.1, 38.4)* | 11.9 (6.14, 22.9)* | 7.79 (4.00, 15.8)* |
| Model 5: Model 3 + preoperative pain | | | | |
| **Some dependence** | 10.8 (6.86, 17.1)† | 13.4 (7.4, 24.0)† | 4.96 (2.92, 9.20)* | 5.09 (2.40, 10.8)* |
| **Complete dependence** | 14.5 (8.50, 24.8)† | 22.2 (11.1, 44.3)* | 8.55 (4.29, 17.0)* | 10.1 (4.51, 22.6)* |

| Model 6: Model 3 + preoperative pain + preoperative Mobility limitation | | | |
|---|---|---|---|
| **Some dependence** | 10.7 (6.78, 17.0)† | 13.2 (7.34, 23.7)* | 4.90 (2.87, 8.37)* | 5.12 (2.32, 11.3)* |
| **Complete dependence** | 14.2 (8.32, 24.3)† | 21.4 (10.6, 43.2)* | 8.26 (4.12, 16.6)* | 10.1 (4.53, 22.7)* |
| *p-value <0.001 | | | |
| † p-value ≤0.01 | | | |
| CI, confidence interval; BMI, body mass index; ASA, American Society of Anesthesiologists | | | |

Post-THA dependence on walking aids had an even stronger relationship with post-THA moderate-severe mobility limitation than with the pain outcome (Table 4). Odds ratio in multivariable-adjusted models ranged from 10-15 for some dependence and 14-25 for complete dependence. For example, odds of moderate-severe mobility limitation in the full multivariable-adjusted model (model 6) at 2-years post-THA were 10.7 (6.78, 17.0) for some dependence and 14.2 (8.32, 24.3) for complete dependence on walking aids (Table 4).

## Post-THA dependence on walking aids and pain and function outcomes in revision THA cohorts

Unadjusted analyses showed that some or complete dependence was associated with higher odds of moderate-severe pain after revision THA (Table 3). Adjustment for variables including preoperative pain and mobility limitation in hierarchical models showed little attenuation in increased odds of moderate-severe pain (Table 4). In the full multivariable-adjusted model, odds of moderate-severe pain at 2-years post-THA were 4.67 (2.76, 7.91) for some dependence and 2.95 (1.65, 5.27) for complete dependence on walking aids (Table 4).

Unadjusted odds of moderate-severe mobility limitation were higher with some dependence and with complete dependence on walking aids (Table 3). Further multivariable-adjusted models showed slight attenuation in odds ratios that ranged 5-16.5-times (Table 4). In the full multivariable-adjusted model, odds of moderate-severe mobility limitation at 2-years post-THA were 4.90 (2.87, 8.37) for some dependence and 8.26 (4.12, 16.6) for complete dependence on walking aids (Table 4).

## Discussion

In this Institutional Joint Registry study, we found that long-term post-THA dependence on walking aids had a strong independent association with PROs 2- and 5-years after primary or revision THA. The higher odds noted were consistent and stable across analyses including primary and revision THA, at 2- and 5-years and across several multivariable-adjusted models, providing further support to the robustness of findings. Several findings merit further discussion.

Most medical practices in the U.S. do not routinely collect pre- and post-arthroplasty patient-reported outcomes measures of pain and function [14], arguably the most important outcomes after arthroplasty. This is primarily due to time and resources constraints, related to the length of some instruments, which may be burdensome to the patients [15]. In the ideal circumstances, well-validated assessments would be administered to all patients pre- and at regular intervals post-arthroplasty; however, this is not practical in busy clinic settings. A practical solution to this problem is the use of single item questions [15] that can be administered as a single self-administered question or assessed by ancillary office staff during the patient check-in. Assessment of walking aids dependence meets this criterion, and given its association with pain and function can serve as a marker for poorer pain and function outcomes in patients who underwent THA.

The association of long-term post-THA dependence on walking aids and moderate-severe pain after THA is a novel finding to our knowledge. Some or complete dependence on walking aids each increased the odds of moderate-severe pain at 2- or 5-years post-THA by 4-times. Importantly, this finding persisted in multivariable-adjusted models that included preoperative pain and/or pre-operative mobility limitation, indicating that the association of dependence on walking aids with pain was independent of demographics (age, gender), clinical variables (comorbidity, BMI, depression, anxiety, diagnosis) and preoperative pain and mobility limitation. Dependence on walking aids is a marker of decreased mobility [9] and frailty [10]. The dependence may be due to arthritis in other lower extremity joints, back pain, balance problems, peripheral neuropathy, previous stroke, leg claudication and other causes [9]. Poor post-THA outcomes are multi-factorial [6,32,33].

Several potential reasons may explain the association of dependence on walking aids with poor pain outcomes in patients post-THA. A recent study showed that frailty predicted intrusive pain in a cohort of 1,705 community-dwelling elderly [34], partially but not completely mediated by age, comorbidity, and depression. Dependence on walking aids associated with decreased physical functioning and mobility likely interferes with the ability to optimally adhere to post-THA physical therapy and rehabilitation, which is the key to best (pain and function) outcomes after arthroplasty [35,36]. Mobility is the most important factor in older person's perceived health, well-being, self-esteem and functional health [37-39] and not surprisingly, the use of walking aids is associated with lower physical functioning and health [40].

These potential mechanisms explain how dependence on walking aids may contribute to suboptimal pain outcomes after THA.

Our findings add to the current knowledge of impact of preoperative use of walking aids on longer hospital stay [11,12] and higher mortality after arthroplasty [13]. Frailty, measured by dependence on walking aids, was associated with more pain and functional limitation in our study. Due to the analyses of both exposure and outcome at the same assessment time, the direction of association is unclear. It is possible that more dependence leads to more pain (see discussion above), more pain leads to a higher likelihood of walking aids dependence or the two co-exist without a dependent relationship. Pain leading to the limitation of person's ability to perform activities of daily living and exercise, is a precipitant of frailty [41]. Conversely, frailty can lead to pain, as shown previously [34]. Since frailty evolves over years and gradually, longitudinal studies with validated assessments of frailty are needed to address this key question of what comes first, pain or frailty. Regardless of the direction of association, given the current knowledge, frailty and persistent pain may create a vicious cycle in some patients after THA, leading to poor overall surgical outcome. Whether targeting pain or mobility can more efficiently improve outcomes in these patients is currently unknown, and should be investigated in future studies.

Our study findings have clinical implications. Not surprisingly, pain and functional outcomes post-arthroplasty are associated with each other [8,42]. A significant finding of our study was that walking aids were associated with poor pain and function outcomes post-THA and may serve as a surrogate. In the absence of validated patient-reported pain and function survey assessments, which can be challenging due to the time and resource constraints in a busy clinical practice, walking aid dependence and its severity can easily be documented and used for targeting clinical care to higher risk patients. Our finding of association of walking aid dependence and its severity (some vs. complete dependence) with pain at 2- and 5-years post-THA further supports that these two key outcomes (pain and mobility) are correlated and moderately associated with each other. Interventions targeting one are likely to benefit both outcomes. Preoperative exercise is associated with reduction in pain and improvement in function in patients waiting for knee/hip arthroplasty [43]. Interventions that target pain, including peri-operative regimen of pregabalin and celecoxib [44], and pain coping behavior [45], improved not only pain but also functional outcomes post-arthroplasty. Several other studies/trials are underway that either target function or pain and examine the effect on pain and function outcomes: [1] targeting function: pre-operative neuromuscular training [46]; [2] targeting pain: mindfulness [47] and pain coping skills [48]. Thus, our study findings support the notion that interventions targeting either pain or mobility will likely positively impact both outcomes post-THA.

The association of post-THA dependence on walking aids and post-THA mobility limitation is intuitive. It is noteworthy that this association was significant even after adjusting for preoperative mobility limitation and pain. Thus, dependence on walking aids is capturing a functional limitation domain different than that captured by preoperative mobility limitation, a novel observation. Higher odds of poor mobility limitations were seen with complete vs. some dependence, providing evidence for dose relationship.

Another significant aspect of this study was that the dependence on walking aids was associated with 10-25 fold-higher odds of moderate-severe mobility limitation and 4-fold higher odds of moderate-severe pain after THA, a highly statistically significant and clinically meaningful association. These odds ratios are much higher than those from the previous studies that have examined association of various demographic and clinical predictors with poor post-THA pain and functional outcomes ranging 1.3-2.1 for moderate severe pain and 1.4-4.5 for moderate-severe mobility limitation [6-8]. Thus, dependence on walking aids is a strong marker of poor PROs post-THA.

Our study has several limitations. Generalizability of our findings from a large single center joint registry study may be appropriately questioned. However, our cohort characteristics are similar to other published studies of THA [49,50] as well as the NIS THA sample [51,52], which supports the generalizability of these findings. Given the cohort study design, residual confounding is possible, despite the adjustment for several covariates and potential confounders in multivariable-adjusted analyses. Given that our main question was to assess association of post-THA dependence on walking aids on post-THA PROs, the assessments were done at the same follow-up and therefore the direction of association could not be determined. In the future, longitudinal studies that assess frailty at frequent intervals post-arthroplasty can help to determine the causality of frailty in poor outcomes post-THA. Telephone survey administration and completion of the survey in the clinic in the presence of clinician may be associated with higher scores than mailed surveys; however, how this impacts the association of walking aids to pain/function outcomes is unknown. Non-response bias may have impacted the results, but it is not clear whether it weakened or strengthened the associations, since the impact of the factors associated with these associations is unknown; their effect (older age, lower BMI, lower ASA class) on pain/mobility outcomes is usually positive, implying that the estimates for those may be lower in our study than actual estimates, had everyone responded. We lacked information regarding the reasons for dependence on walking aids or for cause of persistent pain in the index arthroplasty joint, since this is not collected as part of the arthroplasty registry data. Data on implant stability or malposition were not available at the time of these surveys; therefore, we were unable to investigate the exact causes or contribution of instability/malposition to persistent pain or persistent activity limitation; however, it is unlikely to explain such a large proportion of THA patients with persistent pain or activity limitation. Bilateral THAs were performed in a small proportion of the patents (<20%) and we accounted for bilaterality by using GEE in our models.

## Conclusions

In conclusion, in this large registry-based study, we found that long-term post-THA dependence on walking aids was independently associated with significantly higher odds of moderate-severe pain and moderate-severe mobility limitation after primary and revision THA. These associations were independent of patient demographic and comorbidity characteristics and preoperative pain and mobility limitation, were consistent between primary and revision THA, and persisted in multiple multivariable-adjusted models. The amount of dependence on walking aids was important, with odds of poor outcomes being worse for those with complete dependence vs. some/partial dependence on walking aids. For this elderly cohort, dependence on walking aids is likely an indicator of frailty, and a surrogate of poor pain and function outcomes post-THA. Interventions to reduce frailty, reduce dependence on walking aids and/or improve pain/function outcomes may improve overall patient experience and outcomes post-THA. This will further improve the outcomes for this already successful surgical treatment of hip arthritis.

## Authors' Contributions

JAS designed the study, developed the protocol and obtained IRB approval, analyzed data, and wrote the first draft of the manuscript. DGL reviewed the protocol and provided comments and reviewed analyses. JAS and DGL revised the manuscript and made the decision to submit it.

## Financial Conflict

There are no financial or non-financial conflicts related to this work. J.A.S. has received research and travel grants from Takeda and Savient; and consultant fees from Savient, Takeda, Regeneron and Allergan. D.G.L. has received royalties/speaker fees from Zimmer, has been a paid consultant to Zimmer and has received institutional research funds from DePuy, Stryker and Zimmer.

"The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the United States government."

## Grant Support

## References

1.  Section 3: Inpatient Hospital Stays by Procedure (2009) Exhibit 3.1 Most Frequent All-listed Procedures. HCUP Facts and Figures, HCUP, USA.

2.  Culliford DJ, Maskell J, Beard DJ, Murray DW, Price AJ, et al. (2010) Temporal trends in hip and knee replacement in the United Kingdom: 1991 to 2006. J Bone Joint Surg Br 92: 130-135.

3.  Robertsson O, Bizjajeva S, Fenstad AM, Furnes O, Lidgren L, et al. (2010) Knee arthroplasty in Denmark, Norway and Sweden. Acta Orthop 81: 82-89.

4.  Ethgen O, Bruyere O, Richy F, Dardennes C, Reginster JY (2004) Health-related quality of life in total hip and total knee arthroplasty. A qualitative and systematic review of the literature. J Bone Joint Surg Am 86: 963-974.

5.  Rissanen P, Aro S, Sintonen H, Slatis P, Paavolainen P (1996) Quality of life and functional ability in hip and knee replacements: a prospective study. Qual Life Res 5: 56-64.

6.  Singh JA, Lewallen D (2010) Predictors of pain and use of pain medications following primary Total Hip Arthroplasty (THA): 5,707 THAs at 2-years and 3,289 THAs at 5-years. BMC Musculoskelet Disord 11: 90.

7.  Singh JA, Lewallen DG (2010) Predictors of activity limitation and dependence on walking aids after primary total hip arthroplasty. J Am Geriatr Soc 58: 2387-2393.

8.  Singh JA, Lewallen D (2009) Age, gender, obesity, and depression are associated with patient-related pain and function outcome after revision total hip arthroplasty. Clin Rheumatol 28: 1419-1430.

9.  Bruce DG, Davis WA, Davis TM (2005) Longitudinal predictors of reduced mobility and physical disability in patients with type 2 diabetes: the Fremantle Diabetes Study. Diabetes Care 28: 2441-2447.

10. Koller K, Rockwood K (2013) Frailty in older adults: implications for end-of-life care. Cleveland Clinic journal of medicine 80:168-174.

11. Husted H, Holm G, Jacobsen S (2008) Predictors of length of stay and patient satisfaction after hip and knee replacement surgery: fast-track experience in 712 patients. Acta Orthop 79: 168-173.

12. Raut S, Mertes SC, Muniz-Terrera G, Khanduja V (2012) Factors associated with prolonged length of stay following a total knee replacement in patients aged over 75. Int Orthop 36: 1601-1608.

13. Jameson E, Jones S, Wraith JE (2013) Enzyme replacement therapy with laronidase (Aldurazyme) for treating mucopolysaccharidosis type I. Cochrane Database Syst Rev 9: CD009354.

14. Franklin PD, Harrold L, Ayers DC (2013) Incorporating patient-reported outcomes in total joint arthroplasty registries: challenges and opportunities. Clin Orthop Relat Res 471: 3482-3488.

15. Sloan JA, Zhao X, Novotny PJ, Wampfler J, Garces Y, et al. (2012) Relationship between deficits in overall quality of life and non-small-cell lung cancer survival. J Clin Oncol 30: 1498-1504.

16. McGrory BJ, Morrey BF, Rand JA, Ilstrup DM (1996) Correlation of patient questionnaire responses and physician history in

grading clinical outcome following hip and knee arthroplasty. A prospective study of 201 joint arthroplasties. J Arthroplasty 11: 47-57.

17. Kavanagh BF, Fitzgerald RH, Jr (1985) Clinical and roentgenographic assessment of total hip arthroplasty. A new hip score. Clin Orthop Relat Res 193: 133-140.

18. STROBE Statement. Strengthening the reporting of observational studies in epidemiology

19. Singh JA, O'Byrne M, Harmsen S, Lewallen D (2010) Predictors of moderate-severe functional limitation after primary Total Knee Arthroplasty (TKA): 4701 TKAs at 2-years and 2935 TKAs at 5-years. Osteoarthritis Cartilage 18: 515-521.

20. Bourne R, Mukhi S, Zhu N, Keresteci M, Marin M (2007) Role of obesity on the risk for total hip or knee arthroplasty. Clin Orthop Relat Res 465: 185-188.

21. Singh JA, Gabriel S, Lewallen D (2008) The impact of gender, age, and preoperative pain severity on pain after TKA. Clin Orthop Relat Res 466: 2717-2723.

22. WHO (2000) Obesity: preventing and managing the global epidemic Geneva: World Health Organization.

23. Deyo RA, Cherkin DC, Ciol MA (1992) Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. J Clin Epidemiol 45: 613-619.

24. Charlson ME, Pompei P, Ales KL, MacKenzie CR (1987) A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 40: 373-383.

25. Charlson ME, Sax FL, MacKenzie CR, Braham RL, Fields SD, et al. (1987) Morbidity during hospitalization: can we predict it? J Chronic Dis 40: 705-712.

26. Singh JA, Lewallen DG (2013) Income and patient-reported outcomes (PROs) after primary total knee arthroplasty. BMC Med 11: 62.

27. Dripps RD, Lamont A, Eckenhoff JE (1961) The role of anesthesia in surgical mortality. JAMA 178: 261-266.

28. Weaver F, Hynes D, Hopkinson W, Wixson R, Khuri S, et al. (2003) Preoperative risks and outcomes of hip and knee arthroplasty in the Veterans Health Administration. J Arthroplasty 18: 693-708.

29. Singh JA, Lewallen DG (2013) Medical and psychological comorbidity predicts poor pain outcomes after total knee arthroplasty. Rheumatology (Oxford 52: 916-923.

30. Singh JA, Jensen M, Lewallen D (2013) Predictors of periprosthetic fracture after total knee replacement: an analysis of 21,723 cases. Acta orthopaedica 84: 170-177.

31. Mahomed NN, Liang MH, Cook EF, Daltroy LH, Fortin PR, et al. (2002) The importance of patient expectations in predicting functional outcomes after total joint arthroplasty. J Rheumatol 29: 1273-1279.

32. Huang CS, Cheu YD, Ying J, Wei MH (2011) Association between provider volume and comorbidity on hospital utilization and outcomes of total hip arthroplasty among National Health Insurance enrollees. J Formos Med Assoc 110: 401-409.

33. Koenig K, Huddleston JI 3rd, Huddleston H, Maloney W, Goodman SB (2012) Advanced Age and Comorbidity Increase the Risk for Adverse Events After Revision Total Hip Arthroplasty. J Arthroplasty.

34. Blyth FM, Rochat S, Cumming RG, Creasey H, Handelsman DJ, et al. (2008) Pain, frailty and comorbidity on older men: the CHAMP study. Pain 140: 224-230.

35. Brueilly KE, Pabian P, Straut L, Freve L, Kolber M (2012) Factors contributing to rehabilitation outcomes following hip arthroplasty. Physical Therapy Reviews 17: 301-310.

36. Bade MJ, Stevens-Lapsley JE (2011) Early high-intensity rehabilitation following total knee arthroplasty improves outcomes. J Orthop Sports Phys Ther 41: 932-941.

37. Bourret EM, Bernick LG, Cott CA, Kontos PC (2002) The meaning of mobility for residents and staff in long-term care facilities. J Adv Nurs 37: 338-345.

38. Bowling A, Farquhar M, Grundy E, Formby J (1993) Changes in life satisfaction over a two and a half year period among very elderly people living in London. Soc Sci Med 36: 641-655.

39. Gooding BA, Sloan M, Amsel R (1988) The well-being of older Canadians. The Canadian journal of nursing research = Revue canadienne de recherche en sciences infirmieres 20: 5-18.

40. Andersen DA, Roos BA, Stanziano DC, Gonzalez NM, Signorile JF (2007) Walker use, but not falls, is associated with lower physical functioning and health of residents in an assisted-living environment. Clin Interv Aging 2: 123-137.

41. Morley JE, Haren MT, Rolland Y, Kim MJ (2006) Frailty. Med Clin North Am 90: 837-847.

42. Jones CA, Voaklander DC, Johnston DW, Suarez-Almazor ME (2001) The effect of age on pain, function, and quality of life after total hip and knee arthroplasty. Arch Intern Med 161: 454-460.

43. Gill SD, McBurney H (2013) Does exercise reduce pain and improve physical function before hip or knee replacement surgery? A systematic review and meta-analysis of randomized controlled trials. Arch Phys Med Rehabil 94: 164-176.

44. Huber EO, de Bie RA, Roos EM, Bischoff-Ferrari HA (2013) Effect of pre-operative neuromuscular training on functional outcome after total knee replacement: a randomized-controlled trial. BMC Musculoskelet Disord 14: 157.

45. Carmichael NM, Katz J, Clarke H, Kennedy D, Kreder HJ, et al. (2013) An intensive perioperative regimen of pregabalin and celecoxib reduces pain and improves physical function scores six weeks after total hip arthroplasty: a prospective randomized controlled trial. Pain Res Manag 18: 127-132.

46. Riddle DL, Keefe FJ, Nay WT, McKee D, Attarian DE, et al. (2011) Pain coping skills training for patients with elevated pain catastrophizing who are scheduled for knee arthroplasty: a quasi-experimental study. Arch Phys Med Rehabil 92: 859-865.

47. Dowsey MM, Castle DJ, Knowles SR, Monshat K, Salzberg MR, et al. (2014) The effect of mindfulness training prior to total joint arthroplasty on post-operative pain and physical function: study protocol for a randomised controlled trial. Trials 15: 208.

48. Riddle DL, Keefe FJ, Ang D, Dumenci L (2012) A phase III randomized three-arm trial of physical therapist delivered pain coping skills training for patients with total knee arthroplasty: the KASTPain protocol. BMC Musculoskelet Disord 13: 149.

49. Huddleston JI, Wang Y, Uquillas C, Herndon JH, Maloney WJ (2012) Age and obesity are risk factors for adverse events after total hip arthroplasty. Clin Orthop Relat Res 470: 490-496.

50. Jimenez-Garcia R, Villanueva-Martinez M, Fernandez-de-Las-Penas C, Hernandez-Barrera V, Rios-Luna A, et al. (2011) Trends

in primary total hip arthroplasty in Spain from 2001 to 2008: evaluating changes in demographics, comorbidity, incidence rates, length of stay, costs and mortality. BMC Musculoskelet Disord 12: 43.

51. Bang H, Chiu YL, Memtsoudis SG, Mandl LA, Della Valle AG, et al. (2010) Total hip and total knee arthroplasties: trends and disparities revisited. Am J Orthop (Belle Mead NJ) 39: E95-102.

52. Kirksey M, Chiu YL, Ma Y, Della Valle AG, Poultsides L, et al. (2012) Trends in in-hospital major morbidity and mortality after total joint arthroplasty: United States 1998-2008. Anesth Analg 115: 321-327.