Home-Health-Care Physical Therapy Improves Early Functional Recovery of Medicare Beneficiaries After Total Knee Arthroplasty

Jason R. Falvey, DPT, Michael J. Bade, PhD, Jeri E. Forster, PhD, Robert E. Burke, MD, MS, Jason M. Jennings, MD, Eugene Nuccio, PhD, and Jennifer E. Stevens-Lapsley, PhD

Investigation performed at the University of Colorado, Anschutz Medical Campus, Aurora, Colorado

Background: Home-health-care utilization after total knee arthroplasty (TKA) is increasing. Recent publications have suggested that supervised rehabilitation is not needed to optimize functional recovery after TKA; however, few studies have evaluated patients in home-health-care settings. The objectives of this study were to (1) determine whether physical therapy (PT) utilization is associated with functional improvements for patients in home-health-care settings after TKA and (2) determine which factors are related to utilization of PT.

Methods: This study was an analysis of Medicare home-health-care claims data for patients treated with a TKA in 2012 who received home-health-care services for postoperative rehabilitation. Multivariable linear regression models were used to evaluate relationships between PT utilization and recovery in activities of daily living (ADLs). Negative binomial regression models were used to determine factors associated with PT utilization.

Results: Records from 5,967 Medicare beneficiaries were evaluated. Low home-health-care PT utilization (≤ 5 visits) was associated with less improvement in ADLs compared with 6 to 9 visits, 10 to 13 visits, or ≥ 14 visits. Compared with low home-health-care utilization, utilization of 6 to 9 visits was associated with a 25% greater improvement in ADLs over the home-health-care episode ($p < 0.0001$); 10 to 13 visits, with a 40% greater improvement ($p < 0.0001$); and ≥ 14 visits, with a 50% greater improvement ($p < 0.0001$). The findings remained robust following adjustments for medical complexity, baseline functional status, and home-health-care episode duration. After adjustment, lower PT utilization was observed for patients receiving home health care from rural agencies (10.7% fewer visits, 95% confidence interval [CI] = 7.9% to 13.7%), those with depressive symptoms (4.8% fewer visits, 95% CI = 1.3% to 8.3%), and those with any baseline dyspnea (5.3% fewer visits, 95% CI = 3.1% to 7.5%).

Conclusions: Low home-health-care PT utilization was significantly associated with worse recovery in ADLs after TKA for Medicare beneficiaries, after controlling for medical complexity, baseline function, and home-health-care episode duration. Patients who are served by rural agencies or who have higher medical complexity receive fewer PT visits after TKA and may need closer monitoring to ensure optimal functional recovery.

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

Total knee arthroplasty (TKA) is the most commonly performed surgery in the United States, with >700,000 performed annually¹. This number is expected to increase to 3.5 million annually by the year 2030². TKA is associated with the

largest procedural expenditure by the Centers for Medicare & Medicaid Services (CMS), costing an average of \$23,000 to \$27,000 per procedure³. Post-acute care is responsible for a substantial portion of this cost^{4,5}.

Disclosure: This work was supported by a Promotion of Doctoral Studies II Scholarship from the Foundation for Physical Therapy, the National Institute on Aging Grants T32AG000279 and F31AG056069, and research grants from the American Physical Therapy Association Home Health Section, the Foundation for Physical Therapy, and the Center on Health Services Training and Research (CoHSTAR). Statistical resources were provided by the VA Informatics and Computing Infrastructure (VINCI). None of the funding sources were involved in preparation of the sample, analysis of the data, or drafting of the manuscript. 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/E923>).

The CMS recently introduced the Comprehensive Care for Joint Replacement (CCJR) Bundle. This alternative payment model bundles hospital, post-acute-care, and outpatient costs associated with total joint replacement. These bundles are one example of a broader trend favoring discharge from the hospital to home. Early data on the CCJR has suggested that utilization of home-health-care services by TKA recipients is increasing as a substitute for more costly facility-based care⁶. Utilization of physical therapy (PT) services during an episode of home health care may be an important component for optimal recovery⁷. Recent research has suggested a relationship between higher PT dosage and greater functional recovery⁸; however, others have suggested that delivery of PT services offers minimal long-term benefits for patients after TKA⁹. One recent editorial posited that patients make greater functional recovery after TKA in the absence of formal PT and that PT may actually cause harm¹⁰.

The paucity of research on rehabilitation after TKA has led some researchers to suggest curtailing utilization of PT to reduce costs^{7,11}. However, little research on rehabilitation after TKA has focused on access to PT or the optimal number of PT visits for Medicare beneficiaries receiving home-health-care services. While access to home-health-care services is available in 97% of United States ZIP codes¹², utilization of post-acute-care services after total joint replacement is highly variable across geographic regions¹³. In addition, older adults who are shifted to home health care instead of higher-cost post-acute-care facilities may have more medical complexity, therefore complicating rehabilitation delivery efforts¹⁴.

Thus, the goals of this study were to (1) determine relationships between utilization of PT and functional recovery among Medicare fee-for-service beneficiaries receiving home-health-care services following TKA and (2) determine which factors are related to utilization of home-health-care PT after TKA within this population. We hypothesized that lower PT utilization would be associated with smaller gains in physical function during home-health-care episodes and that geographic factors, rural status, and higher medical complexity would each be associated with lower PT utilization.

Materials and Methods

Study Design

We performed an analysis of 2012 Medicare home-health-care administrative data. In short, Medicare beneficiaries qualify for home-health-care services if they are homebound and need at least 1 skilled medical service. Generally, patients receiving home health care have more complex medical conditions than those who are discharged directly to outpatient therapy after a TKA. Home health care is paid for in comprehensive bundles that take into account both clinical and functional complexity and adjust upward with increasing therapy utilization.

We identified Medicare beneficiaries who were listed across all of 3 data files: the 2012 Medicare Provider and Analysis Review (MedPAR) Research Identifiable File (RIF), the 2012 home-health-care RIF, and the 2012 Outcome and Assessment Information Set (OASIS). The MedPAR file contains hospitalization procedure and cost data, comorbidity data, and beneficiary sociodemographic information. The home-health-care RIF

contains home-health-care claims data; the OASIS file complements these data by providing beneficiary functional status and degree of medical complexity. Beneficiaries listed in all 3 data sets were linked by a unique Medicare beneficiary ID number. Lastly, we used the Medicare Provider of Services (POS) file to extract home-health-care agency characteristics such as urban or rural status and whether or not the agency was for-profit.

Sample Preparation

We verified receipt of TKA in the MedPAR database (International Classification of Diseases-Ninth Revision [ICD-9] procedure code 80.54). We extracted data for Medicare beneficiaries who had used home-health-care services within 30 days after a primary TKA in 2012. We limited the sample to beneficiaries using home-health-care services for total joint replacement aftercare, defined by an OASIS primary ICD-9 code of V54.81 or V57.1. This excluded patients receiving care primarily for another condition, such as heart failure. If patients had multiple home-health-care episodes following a TKA in a calendar year, only the first home-health-care admission for post-TKA rehabilitation was included.

Outcome Measures

Our primary outcome of interest was a change in activities of daily living (ADLs) function. Because each ADL is scored on a separate scale within the OASIS tool, researchers developed and validated a standardized composite ADL score for the OASIS^{15,16}. This scale has been used to describe ADL function in other Medicare home-health-care populations¹⁷. Each ADL is scored on a continuous scale of 0.0 to 1.0, and the scores are summed to obtain a standardized composite functional score between 1 and 9, with higher scores indicating greater impairment. Moving from 1 to 0 within an ADL category represents a shift from complete dependence to complete independence; incremental improvements of ≥ 0.14 point represent meaningful reductions in the need for assistance or devices to complete ADL tasks. We included the following 9 ADLs: upper and lower body dressing, bathing, toileting, toileting hygiene, transferring, walking, preparing light meals, and grooming. ADL change was the difference between ADL scores measured at admission to and discharge from home health care.

The secondary outcome of interest was the number of PT visits utilized during the home-health-care episode. We extracted relevant codes related to PT utilization and summed the number of codes over the first 60-day episode of home care following hospital discharge. We categorized PT utilization as low (0 to 5 visits), moderate (6 to 9 visits), high (10 to 13 visits), or very high (≥ 14 visits) on the basis of Medicare utilization cut-points for home-health-care agencies.

Clinical Characteristics

We used the Charlson Comorbidity Index (CCI) to characterize medical complexity¹⁸. ICD-9 codes from the MedPAR file were mapped to the CCI using a validated algorithm¹⁹. Hospital length of stay and admission type (traumatic or elective) were extracted from MedPAR.

Medical and functional impairments present on admission to home health care were captured from the OASIS

TABLE I Sample Demographics

Characteristic	Full Sample (N = 5,967)	PT Use			
		Low: ≤5 Visits (N = 690)	Moderate: 6-9 Visits (N = 2,495)	High: 10-13 Visits (N = 2,085)	Very High: ≥14 Visits (N = 697)
Age (<i>no. [%]</i>)					
<65 yr (Medicare disability beneficiary)	611 (10.2)	87 (12.6)	241 (9.7)	213 (10.2)	70 (10.0)
65-84 yr	4,954 (83.2)	561 (81.3)	2,083 (83.5)	1,741 (83.5)	579 (83.1)
≥85 yr	392 (6.6)	42 (6.1)	171 (6.9)	131 (6.3)	48 (6.9)
Female (<i>no. [%]</i>)	4,044 (67.8)	440 (63.8)	1,638 (65.7)	1,456 (69.8)	510 (73.2)
Race (<i>no. [%]</i>)					
Caucasian	5,313 (89.0)	622 (90.1)	2,260 (90.6)	1,838 (88.2)	593 (85.1)
African-American	434 (7.3)	42 (6.1)	149 (6.0)	173 (8.3)	70 (10.0)
Other	220 (3.7)	26 (3.8)	86 (3.4)	74 (3.5)	34 (4.9)
CCI (<i>no. [%]</i>)					
0	3,166 (53.1)	313 (45.4)	1,383 (55.4)	1,116 (53.5)	354 (50.8)
1	1,728 (29.0)	236 (34.2)	687 (27.5)	597 (28.6)	208 (29.8)
≥2	1,073 (18.0)	141 (20.4)	425 (17.0)	372 (17.8)	135 (19.4)
Elective hospital admission (<i>no. [%]</i>)	5,635 (94.4)	654 (94.8)	2,368 (94.9)	1,960 (94.0)	653 (93.7)
Median hospital length of stay (IQR) (<i>days</i>)	3.0 (3.0-3.0)	3.0 (3.0-3.0)	3.0 (3.0-3.0)	3.0 (3.0-3.0)	3.0 (3.0-4.0)
Mean (SD) home-health-care admission ADL score (higher = worse)	4.6 (0.9)	4.3 (1.0)	4.5 (0.9)	4.7 (0.9)	4.9 (0.9)
Any depressive symptoms (<i>n</i> = 5,766) (<i>no. [%]</i>)	588 (10.2)	82 (12.3)	228 (9.5)	215 (10.7)	63 (9.3)
Any prior post-acute care (<i>no. [%]</i>)	1,275 (21.4)	198 (28.7)	525 (21.0)	434 (20.8)	118 (16.9)
Any baseline dyspnea (<i>no. [%]</i>)	2,963 (49.7)	316 (45.8)	1,143 (46.0)	1,069 (51.3)	435 (62.4)
Severe pain at baseline (<i>no. [%]</i>)	1,648 (27.6)	160 (23.2)	682 (27.3)	603 (28.9)	203 (29.1)
Living alone (<i>no. [%]</i>)	1,264 (21.2)	168 (24.3)	509 (20.4)	457 (21.9)	130 (18.7)
Mean (SD) duration of home health care (<i>days</i>)	20.8 (11.5)	11.0 (7.9)	16.1 (6.9)	24.2 (9.0)	37.7 (12.8)
Rural agency (<i>n</i> = 5,947) (<i>no. [%]</i>)	1,024 (17.2)	120 (17.4)	427 (17.2)	354 (17.0)	123 (17.7)
For-profit agency (<i>n</i> = 5,949) (<i>no. [%]</i>)	3,160 (53.1)	304 (44.1)	1,104 (44.4)	1,238 (59.6)	514 (73.7)
Census region (<i>no. [%]</i>)					
South	2,641 (44.3)	196 (28.4)	897 (36.0)	1,065 (51.1)	483 (69.3)
West	836 (14.0)	139 (20.1)	407 (16.3)	236 (11.3)	54 (7.7)
Midwest	1,370 (23.0)	173 (25.1)	654 (26.2)	457 (21.9)	86 (12.3)
Northeast	1,120 (18.8)	182 (26.4)	537 (21.5)	327 (15.7)	74 (10.6)

database. Depressive symptoms were defined as a score of ≥1 on the Patient Health Questionnaire-2 (PHQ-2) depression scale. Constant, activity-limiting baseline pain was categorized as present (a score of 4) or absent (a score of ≤3) on the OASIS pain assessment. The home-health-care episode duration in days, defined as the time from the start of home health care to either discharge or admission to an inpatient facility, was also extracted from the OASIS.

Characteristics of Home-Health-Care Agency

The ownership status of the home-health-care agency and whether it was designated as urban or rural on the basis of the Medicare Core-Based Statistical Areas were extracted from the Medicare POS file. To adjust for regional differences in care delivery, we categorized participants as living in 1 of 4 Census Bureau regions (Northeast, West, Midwest, and South).

TABLE II Improvement in ADL Function by PT Utilization

PT Utilization	Mean Improvement in ADL Score (95% CI) (points)	
	Unadjusted	Adjusted*
≤5 visits	1.67 (1.62-1.73)	1.91 (1.86-1.96)
6-9 visits	2.09 (2.06-2.13)†	2.13 (2.09-2.17)†
10-13 visits	2.34 (2.29-2.39)†	2.22 (2.17-2.27)†
≥14 visits	2.50 (2.43-2.58)†	2.22 (2.15-2.28)†

*Adjusted for age, sex, baseline ADL function, non-elective admission, duration of home health care, living alone, CCI, baseline dyspnea, and presence of severe pain. †P < 0.0001 compared with low PT utilization.

Statistical Analysis

Descriptive statistics were calculated using the mean and standard deviation (SD), median and interquartile range (IQR), or the number and percentage. Unadjusted and adjusted linear regression models were then developed to evaluate the association between PT utilization and ADL change during the episode of home health care. The adjusted model regressed functional change on PT utilization, adjusting for demographic variables (age and sex) and medical status factors (elective or traumatic surgical admission, baseline physical function, CCI, baseline dyspnea, severe pain, and living alone) that impact ADL recovery. We also adjusted for time spent in home health care to account for natural recovery that occurs after TKA.

We then fit a series of univariable regression models to determine which factors are related to the number of PT visits received during an episode of home health care. Negative binomial regression was used to model PT visits received. An

offset for home-health-care length of stay (log-time) was included in all models to adjust for differing durations of PT exposure time for each patient. The exponentiated beta coefficients in negative binomial models represent the ratio of differences in PT utilization between variable levels.

Candidate variables related to utilization included CCI score, presence of depressive symptoms, presence of baseline dyspnea, geographic region, rural agency status, geographic region, and agency profit status. All candidate variables were included in a fully adjusted model, and then backward selection was used to remove the most non-significant variable in each iteration of the model until all candidate variables had a p value of <0.05. Race, sex, age, baseline ADL function, post-acute-care utilization, hospital length of stay, non-elective admission, and living alone were adjusted for in all models.

Because OASIS data are used to generate payment for home-health-care agencies, missing data were minimal. Any missing data in the model were considered to be missing at random, and the percentage of missing data did not exceed 5% for any variable. All statistical analysis was conducted using SAS 9.4 software (SAS Institute).

Results

Overall, 8,127 patients received home-health-care services in 2012 following a TKA. After applying sample selection criteria, 5,967 patients were included for analysis. Overall demographics of the sample are presented in Table I. The median cost of home-health-care episodes extracted from the home-health-care RIF was \$2,949 (IQR = \$2,494 to \$3,529) (2012 U.S. dollars), and 4.1% of the sample was admitted to an inpatient facility during home health care. The median time from hospital discharge to home-health-care admission was 2 days.

TABLE III Predictors of PT Utilization After TKA

Predictor	Unadjusted Estimate (Std. Error)	% Difference (95% CI)	Adjusted Estimate (Std. Error)*	% Difference (95% CI)
Rural agency	-0.08 (0.01)	-7.7 (-10.6, -4.9)	-0.11 (0.01)	-10.7 (-13.7, -7.9)
For-profit agency	0.03 (0.01)	2.7 (0.1, 4.8)	—	—
CCI (ref.: 0)				
1	-0.05 (0.01)	-5.1 (-2.7, -7.6)	-0.03 (0.01)	-3.0 (-5.4, -0.7)
≥2	-0.06 (0.01)	-6.4 (-3.5, -9.3)	-0.03 (0.01)	-2.7 (-5.4, 0.2)
Any depressive symptoms	-0.08 (0.02)	-8.0 (-4.3, -12.0)	-0.05 (0.02)	-4.8 (-8.3, -1.3)
Any baseline dyspnea	-0.06 (0.01)	-5.7 (-3.6, -7.9)	-0.05 (0.01)	-5.3 (-7.5, -3.1)
Severe baseline pain	0.05 (0.01)	4.9 (2.6, 7.3)	0.05 (0.01)	5.4 (3.0, 7.8)
Census region (ref.: West)				
Midwest	0.02 (0.02)	2.4 (-1.2, 6.2)	0.05 (0.02)	4.7 (1.2, 8.3)
Northeast	-0.01 (0.02)	-0.9 (-4.6, 2.9)	0.04 (0.02)	4.0 (0.0, 7.9)
South	0.08 (0.02)	7.7 (4.3, 11.1)	0.10 (0.02)	10.0 (7.0, 13.1)

*Model adjusted for hospital length of stay, non-elective admission, baseline ADL function, prior post-acute-care use, age, sex, race, and living alone.

PT and Functional Change

Patients who completed an episode of home health care had an average improvement (decrease) of 2.1 points in the impairment score on the 1 to 9-point ADL scale over the home-health-care episode. Greater ADL improvements were seen with increasing PT utilization, with score attenuations noted as the number of visits increased to ≥ 10 (Table II). Compared with low utilizers of PT, moderate utilizers had a 25% greater improvement in ADL function over the home-health-care episode (mean ADL score difference, 0.42; $p < 0.0001$), high utilizers had a 40% greater improvement (mean difference, 0.67; $p < 0.0001$), and very high utilizers had a 50% greater improvement (mean difference, 0.83; $p < 0.0001$).

PT utilization remained an independent predictor of functional recovery in the adjusted model (Table II). Compared with low utilizers, moderate utilizers had a 12% greater improvement (mean difference, 0.22; $p < 0.0001$), high utilizers had a 16% greater improvement (mean difference, 0.31; $p < 0.0001$), and very high utilizers also had a 16% greater improvement (mean difference, 0.31; $p < 0.0001$). However, the difference between those who received a moderate PT dosage and those who received a high or very high PT dosage did not constitute a minimal clinically important difference in ADL performance. The overall R^2 value of the adjusted model was 0.68.

PT Utilization

Results from the univariable and multivariable negative binomial models predicting frequency of PT utilization are presented in Table III. In the univariable analysis, severe baseline pain and receiving care in the South Census Bureau region were associated with higher PT utilization. Living in a rural setting, higher CCI scores, depressive symptoms, and baseline dyspnea were all associated with lower PT utilization.

Rural location, baseline dyspnea, and depressive symptoms remained significantly associated with a lower utilization of PT in the adjusted model. Patients in rural settings had 10.7% (95% confidence interval [CI] = 7.9% to 13.7%) fewer visits, those with depressive symptoms received 4.8% (95% CI = 1.3% to 8.3%) fewer visits, and those with any baseline dyspnea received 5.3% (95% CI = 3.1% to 7.5%) fewer visits. Higher PT utilization was observed for patients receiving care in the South (10.0% more visits, 95% CI = 7.0% to 13.1%).

Discussion

This study is the first of which we are aware to investigate the effect of home-health-care PT-visit dosage on functional recovery after TKA in a large administrative data set. Our data suggest that lower utilization of PT was associated with a significantly lower magnitude of ADL improvement for patients receiving home-health-care services after TKA. Homebound Medicare beneficiaries appear to achieve optimal functional recovery when they receive 6 to 9 PT visits; additional visits were not associated with clinically meaningful improvements in ADL function. Living in a rural area or having higher medical complexity was associated with receiving fewer PT visits. These findings may help guide physicians and payers to prescribe op-

timal therapy dosages for the growing population of patients who utilize home-health-care rehabilitation after TKA.

Optimizing early ADL outcomes may be especially important for the estimated 20% to 30% of Medicare beneficiaries who forego outpatient therapy and instead terminate formal rehabilitation in post-acute or home-health-care settings^{20,21}. In our study, patients who received ≤ 5 visits of supervised home-health-care PT had blunted ADL recovery compared with those who received more. However, we also found that the benefit of home-health-care PT attenuates after 9 visits, suggesting that 6 to 9 PT visits is the optimal number to maximize function in a resource-efficient manner. This is a novel finding in a medically complex post-TKA population that contrasts with prior studies that suggested that no supervised PT is required to promote functional recovery after TKA^{10,22,23}. However, those studies mostly evaluated healthier post-TKA populations, excluding patients with a high comorbidity burden limiting participation in rehabilitation or those who could not travel to outpatient clinics (that is, homebound patients). Because low PT utilizers in our study were more likely to have received prior post-acute care, had less social support, and had more medical complexity, they may have been even more likely to forego outpatient PT and end formal rehabilitation in home-health-care settings²⁰, thus elevating the importance of functional outcomes during home health care. Incomplete recovery of ADL function may leave patients at risk for future hospitalization or institutionalization^{24,25}.

While the magnitude of improvements in ADL function appears small, they represent clinically meaningful improvements in functional independence. For example, an improvement in walking ability from the need for an assistive device to no device (an important outcome for many patients) is represented by an improvement of 0.14 point on the validated scale used in this study. Utilization of ≥ 6 PT visits was associated with gains of 1.5 times this magnitude in the adjusted models, suggesting that higher PT utilization results in clinically meaningful improvements in ADL function. This increase in ADL independence is likely associated with gains in strength and range of motion that are important for success after TKA²⁶.

Disparities were observed in the number of PT visits after TKA among home-health-care settings. The strongest factor associated with reduced PT utilization was living in a rural environment, which was consistent with our hypothesis. Depressive symptoms, baseline dyspnea, and higher CCI scores were also associated with lower PT utilization. These disparities suggest that it may be prudent to more closely monitor PT participation by rural or medically complex patients, intervene to address barriers to participation, and consider other interventions such as telerehabilitation visits to supplement PT access for this vulnerable population. Additionally, this study shows that utilization in the South Census region is higher than in other regions of the country, even after accounting for population differences. Surgeons may be able to use these findings to reduce costly overutilization.

This study has limitations. First, we evaluated only patients who used home-health-care services after TKA, so our findings

do not represent other Medicare populations who use outpatient services. In addition, we used administrative data and thus may have underestimated or overrepresented certain comorbidities. We also limited the sample to Medicare beneficiaries, which means that the results are not generalizable to other payers.

While these data did not include any patients participating in care bundles, agencies may have already begun changing care patterns. In addition, because we did not have access to outpatient data, it is unknown whether patients who received home-health-care services routinely went on to outpatient services. However, historical data suggest that there is a large cohort of patients who end their post-TKA rehabilitation care after receiving home health care²⁰, so we think that the findings are independently valuable in promoting improvements to care delivery in this setting. Future studies should evaluate outcomes for patients who successfully transition to outpatient rehabilitation.

In conclusion, the optimal utilization of PT in home-health-care settings to promote optimal early ADL recovery after TKA appears to be 6 to 9 visits. Patients in rural areas and those with greater medical complexity receive fewer overall PT visits, suggesting a need for additional monitoring to ensure their appropriate functional recovery. ■

Jason R. Falvey, DPT^{1,2}
Michael J. Bade, PhD¹
Jeri E. Forster, PhD^{1,2}

Robert E. Burke, MD, MS²
Jason M. Jennings, MD^{3,4}
Eugene Nuccio, PhD⁵
Jennifer E. Stevens-Lapsley, PhD^{1,6}

¹Physical Therapy Program, Department of Physical Medicine and Rehabilitation, University of Colorado, Anschutz Medical Campus, Aurora, Colorado

²Denver Veterans Affairs Medical Center, Denver, Colorado

³Colorado Joint Replacement, Porter Adventist Hospital, Denver, Colorado

⁴Department of Mechanical and Materials Engineering, University of Denver, Denver, Colorado

⁵Division of Health Care Policy & Research, University of Colorado School of Medicine, Aurora, Colorado

⁶Veterans Affairs Geriatric Research, Education and Clinical Center, Denver, Colorado

E-mail address for J.R. Falvey: Jason.Falvey@ucdenver.edu

ORCID iD for J.R. Falvey: [0000-0002-9063-0617](https://orcid.org/0000-0002-9063-0617)

ORCID iD for M.J. Bade: [0000-0002-7985-8565](https://orcid.org/0000-0002-7985-8565)

ORCID iD for J.E. Forster: [0000-0002-7955-9127](https://orcid.org/0000-0002-7955-9127)

ORCID iD for R.E. Burke: [0000-0002-9521-8699](https://orcid.org/0000-0002-9521-8699)

ORCID iD for J.M. Jennings: [0000-0002-2047-783X](https://orcid.org/0000-0002-2047-783X)

ORCID iD for E. Nuccio: [0000-0001-8992-424X](https://orcid.org/0000-0001-8992-424X)

ORCID iD for J.E. Stevens-Lapsley: [0000-0002-8118-378X](https://orcid.org/0000-0002-8118-378X)

References

- Agency for Healthcare Research and Quality. Most frequent operating room procedures performed in US hospitals, 2003-2012. 2014 Dec. <https://www.hcup-us.ahrq.gov/reports/statbriefs/sb186-Operating-Room-Procedures-United-States-2012.pdf>. Accessed 2016 Jul 8.
- Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am*. 2007 Apr;89(4):780-5.
- Siddiqi A, White PB, Mistry JB, Gwam CU, Nace J, Mont MA, Delanois RE. Effect of bundled payments and health care reform as alternative payment models in total joint arthroplasty: a clinical review. *J Arthroplasty*. 2017 Aug;32(8):2590-7. Epub 2017 Mar 20.
- Cram P, Ravi B, Vaughan-Sarrazin MS, Lu X, Li Y, Hawker G. What drives variation in episode-of-care payments for primary TKA? An analysis of Medicare administrative data. *Clin Orthop Relat Res*. 2015 Nov;473(11):3337-47. Epub 2015 Aug 4.
- Slover JD, Mullaly KA, Payne A, Iorio R, Bosco J. What is the best strategy to minimize after-care costs for total joint arthroplasty in a bundled payment environment? *J Arthroplasty*. 2016 Dec;31(12):2710-3. Epub 2016 May 20.
- Jubelt LE, Goldfeld KS, Chung WY, Blecker SB, Horwitz LI. Changes in discharge location and readmission rates under Medicare bundled payment. *JAMA Intern Med*. 2016 Jan;176(1):115-7.
- Ong KL, Lotke PA, Lau E, Manley MT, Kurtz SM. Prevalence and costs of rehabilitation and physical therapy after primary tja. *J Arthroplasty*. 2015 Jul;30(7):1121-6. Epub 2015 Feb 28.
- Pua YH, Seah FJ, Poon CL, Tan JW, Liaw JS, Chong HC. Association between rehabilitation attendance and physical function following discharge after total knee arthroplasty: prospective cohort study. *Osteoarthritis Cartilage*. 2017 Apr;25(4):462-9. Epub 2016 Oct 31.
- Artz N, Elvers KT, Lowe CM, Sackley C, Jepson P, Beswick AD. Effectiveness of physiotherapy exercise following total knee replacement: systematic review and meta-analysis. *BMC Musculoskelet Disord*. 2015 Feb 7;16(1):15.
- Wickline AB. Letter to the editor on "arthrofibrosis associated with total knee arthroplasty". *J Arthroplasty*. 2018 Mar;33(3):968. Epub 2017 Nov 21.
- Moffet H, Tousignant M, Nadeau S, Mérette C, Boissy P, Corriveau H, Marquis F, Cabana F, Ranger P, Belzile ÉL, Dimentberg R. In-home telerehabilitation compared with face-to-face rehabilitation after total knee arthroplasty: a non-inferiority randomized controlled trial. *J Bone Joint Surg Am*. 2015 Jul 15;97(14):1129-41.
- Wang Y, Leifheit-Limson EC, Fine J, Pandolfi MM, Gao Y, Liu F, Eckenrode S, Lichtman JH. National trends and geographic variation in availability of home health care: 2002-2015. *J Am Geriatr Soc*. 2017 Jul;65(7):1434-40. Epub 2017 Mar 21.
- Burke RE, Jones CD, Coleman EA, Falvey JR, Stevens-Lapsley JE, Ginde AA. Use of post-acute care after hospital discharge in urban and rural hospitals. *Am J Accountable Care*. 2017 Mar;5(1):16-22. Epub 2017 Mar 10.
- Rosati RJ, Russell D, Peng T, Brickner C, Kurowski D, Christopher MA, Sheehan KM. Medicare home health payment reform may jeopardize access for clinically complex and socially vulnerable patients. *Health Aff (Millwood)*. 2014 Jun;33(6):946-56.
- Fortinsky RH, Garcia RI, Joseph Sheehan T, Madigan EA, Tullai-McGuinness S. Measuring disability in Medicare home care patients: application of Rasch modeling to the outcome and assessment information set. *Med Care*. 2003 May;41(5):601-15.
- Scharpf TP, Madigan EA. Functional status outcome measures in home health care patients with heart failure. *Home Health Care Serv Q*. 2010 Oct;29(4):155-70.
- Madigan EA, Gordon N, Fortinsky RH, Koroukian SM, Piña I, Riggs JS. Predictors of functional capacity changes in a US population of Medicare home health care (HHC) patients with heart failure (HF). *Arch Gerontol Geriatr*. 2012 May-Jun;54(3):e300-6. Epub 2011 Sep 6.
- Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40(5):373-83.
- Quan H, Sundararajan V, Halfon P, Fong A, Burnand B, Luthi JC, Saunders LD, Beck CA, Feasby TE, Ghali WA. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care*. 2005 Nov;43(11):1130-9.
- DeJong G, Tian W, Smout RJ, Horn SD, Putman K, Smith P, Gassaway J, Davanzo JE. Use of rehabilitation and other health care services by patients with joint

replacement after discharge from skilled nursing and inpatient rehabilitation facilities. *Arch Phys Med Rehabil*. 2009 Aug;90(8):1297-305.

21. Oatis CA, Li W, DiRusso JM, Hoover MJ, Johnston KK, Butz MK, Phillips AL, Nanovic KM, Cummings EC, Rosal MC, Ayers DC, Franklin PD. Variations in delivery and exercise content of physical therapy rehabilitation following total knee replacement surgery: A cross-sectional observation study. *Int J Phys Med Rehabil*. 2014;Suppl 5:002. Epub 2014 Apr 22.

22. Rajan RA, Pack Y, Jackson H, Gillies C, Asirvatham R. No need for outpatient physiotherapy following total knee arthroplasty: a randomized trial of 120 patients. *Acta Orthop Scand*. 2004 Feb;75(1):71-3.

23. Kramer JF, Speechley M, Bourne R, Rorabeck C, Vaz M. Comparison of clinic- and home-based rehabilitation programs after total knee arthroplasty. *Clin Orthop Relat Res*. 2003 May;410:225-34.

24. Portegijs E, Buurman BM, Essink-Bot ML, Zwiderman AH, de Rooij SE. Failure to regain function at 3 months after acute hospital admission predicts institutionalization within 12 months in older patients. *J Am Med Dir Assoc*. 2012 Jul;13(6):569.e1-7. Epub 2012 May 8.

25. Boyd CM, Landefeld CS, Counsell SR, Palmer RM, Fortinsky RH, Kresevic D, Burant C, Covinsky KE. Recovery of activities of daily living in older adults after hospitalization for acute medical illness. *J Am Geriatr Soc*. 2008 Dec;56(12):2171-9.

26. Mizner RL, Petterson SC, Clements KE, Zeni JA Jr, Irrgang JJ, Snyder-Mackler L. Measuring functional improvement after total knee arthroplasty requires both performance-based and patient-report assessments: a longitudinal analysis of outcomes. *J Arthroplasty*. 2011 Aug;26(5):728-37. Epub 2010 Sep 20.