

# Optimal Duration of Physical Therapy Following Total Knee Arthroplasty

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Gregory Benes, BS<sup>1</sup> , Zachary Adams, MD<sup>1</sup>,  
Michael Dubic, MD<sup>1</sup>, Justin David, MD<sup>1</sup>, Claudia Leonardi, PhD<sup>2</sup>,  
Amy Bronstone, PhD<sup>3</sup>, and Vinod Dasa, MD<sup>3</sup>

## Abstract

**Aims & Objectives:** The purpose of this study was to identify patient characteristics associated with engagement and completion of physical therapy (PT) following total knee arthroplasty (TKA) and examine the relationship between number of PT sessions attended and outcomes during the first 12 weeks after surgery. **Methods:** Patients underwent unilateral primary TKA by a single surgeon and were advised to complete 17 PT sessions over 6 weeks at a hospital-affiliated facility. Analyses examined predictors of PT engagement (attendance of  $\geq 2$  sessions) and completion (attendance of  $17 \pm 1$  sessions) within 6 weeks and associations between number of PT sessions attended and changes in range of motion (ROM) and Knee Injury and Osteoarthritis Outcome Score (KOOS) values. **Results:** Patients living  $< 40$  km were more likely to be engaged in PT than those living  $\geq 40$  km from the clinic ( $P < .0001$ ). Among patients who completed PT within 6 weeks, 95.0%, 85.1%, and 56.4% achieved flexion of, respectively,  $\geq 90^\circ$ ,  $\geq 100^\circ$ , and  $\geq 110^\circ$ . Among engaged patients, the active flexion thresholds of  $\geq 90^\circ$ ,  $\geq 100^\circ$ , and  $\geq 110^\circ$  were achieved by, respectively, 94.4%, 82.5%, and 58.1% by 6 weeks and by 96.7%, 92.1%, and 84.2% by 12 weeks. Improvement in KOOS Symptoms ( $P = .029$ ), Function in daily living ( $P = .030$ ) and quality of life ( $P = .031$ ) linearly decreased as number of PT sessions increased. **Conclusions:** These results raise the question of whether patients who meet satisfactory outcomes before completing 6 weeks of prescribed PT and those who attend more PT sessions than prescribed may be over-utilizing healthcare resources without additional benefit.

## Keywords

adult reconstructive surgery, geriatric medicine, physical medicine and rehabilitation, physical therapy, systems of care

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## Introduction

Total knee arthroplasty (TKA) is a common orthopedic surgery aimed at reducing pain and restoring function for patients with end-stage knee osteoarthritis. Physical therapy (PT) is universally recommended for patients following TKA as it has been associated with improved pain, range of motion (ROM), muscle strength, and function,<sup>1,2</sup> as well as a shorter duration of opioid use<sup>3</sup> and lower risk of long-term opioid use after surgery.<sup>4</sup>

<sup>1</sup>School of Medicine, Louisiana State University Health Sciences Center, New Orleans, LA, USA

<sup>2</sup>Department of Behavioral and Community Health Sciences, School of Public Health, Louisiana State University Health Sciences Center, New Orleans, LA, USA

<sup>3</sup>Department of Orthopaedics, School of Medicine, Louisiana State University Health Sciences Center, New Orleans, LA, USA

### Corresponding Author:

Vinod Dasa, MD, Department of Orthopaedic Surgery, Louisiana State University Health Sciences Center, 2000 Canal Street, New Orleans, LA 70112, USA.

Email: [vdasa@lsuhsc.edu](mailto:vdasa@lsuhsc.edu)



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Postoperative knee ROM is a critical TKA outcome as it is strongly associated with patient satisfaction.<sup>5</sup>

Patients who are non-compliant with supervised PT protocols may not attain the maximum benefits of TKA. Therefore, it is important to understand the factors that influence PT attendance and completion. Studies that have evaluated predictors of PT non-attendance among patients with various musculoskeletal issues have found that pragmatic and financial factors, including greater travel distance to the clinic, transportation difficulties, longer time between appointments, Medicaid/Medicare insurance, and cost of care, are key predictors of PT non-attendance.<sup>6-8</sup> Because these studies included patients with a broad range of musculoskeletal issues, it is not clear to what extent findings can be generalized to the TKA population. To date, only one study has quantitatively examined predictors of PT attendance after TKA.<sup>9</sup> This prospective cohort study conducted in Singapore found that TKA patients who attended two or more PT sessions were more likely to be younger, have a lower BMI, report better preoperative health, have a shorter length of hospital stay, and use a smaller gait aid preoperatively and at hospital discharge, than patients who attended no PT sessions or only one session.<sup>9</sup> This study had several important limitations. It was conducted in a racially homogeneous population in a country with universal healthcare; did not evaluate race/ethnicity or pragmatic/financial variables as predictors; and did not conduct a multivariable analysis to determine the most salient independent predictors of PT attendance.<sup>9</sup> To address this gap in the literature, a major aim of present study will conduct a multivariable analysis to identify independent predictors of PT attendance, including travel distance, race/ethnicity, and type of health insurance, in a cohort of racially diverse and heterogeneous TKA patients treated in the United States (US). To our knowledge, this will be the first study conducted in the US to examine predictors of PT attendance following TKA.

Although PT in general has been associated with improved outcomes following PT, it is unclear whether there is an optimal “dose” of supervised PT needed to achieve acceptable outcomes. Only one previous study — the prospective cohort study conducted in Singapore described above — has addressed this question.<sup>9</sup> This study found that attending 10 supervised PT sessions after TKA was associated with a statistically and clinically significant improvement in self-reported physical function 6 months after TKA compared to attending only one PT session, and that additional PT sessions beyond 10 did not appreciably improve this outcome.<sup>9</sup> Because these study findings have not been corroborated or shown to be generalized to a US TKA population, a second aim of the proposed study is to investigate the

dose-relationship between supervised PT and patient outcomes 6 weeks and 12 weeks after TKA.

The present study, which focuses on a diverse sample of TKA patients treated in the US, was designed to address two questions: (1) What patient characteristics are independently associated with engagement in and completion of prescribed supervised PT following TKA? and (2) What is the relationship between the number of PT sessions attended after TKA and clinical outcomes 6 weeks and 12 weeks after TKA?

## Methods

A retrospective chart review was conducted of all patients who underwent unilateral primary TKA performed by a single orthopedic surgeon (VD) at a university-based private academic hospital between January 1, 2016, and December 31, 2019. The surgery was outpatient and most patients returned home the same day barring any complications. The study was approved by the academic institution’s institutional review board.

### Physical Therapy Protocol

Patients were referred for PT to the hospital-affiliated clinic located near the surgical hospital for initial evaluation and treatment within 1-3 days following discharge; no home exercises were recommended upon discharge. Patients who received home-based PT, PT remotely via telehealth, or who attended PT at an unaffiliated PT clinic were excluded. The same rehabilitation program was applied to all patients as outlined in [Supplemental File 1](#). Patients were prescribed the facility’s protocol for postoperative TKA PT consisting of 17 PT sessions completed over 6 weeks (three sessions during week 1, four sessions during week 2, three sessions per week during weeks 3-4, and two sessions per week during weeks 5-6). The physical therapist had discretion to modify the number of PT sessions based on their assessment of each patient’s progress. The surgeon strongly encouraged patients who were noncompliant with PT attendance or who were making poor progress on recover goals to engage in aggressive PT and warned them that a manipulation under anesthesia would be required if their ROM did not improve.

Physical therapy (PT) engagement was defined as attending at least two PT sessions and PT completion as attending 17 PT sessions within a 6-week period. The relationship between PT completion and patient characteristics was evaluated only for patients who attended at least two PT sessions and who received PT exclusively at the hospital-affiliated facility because we were not able to ascertain whether patients completed the full course of prescribed PT at outside facilities.

## Data Collection

The patient electronic medical record (EMR) was reviewed to capture patient characteristics, including age, sex, race/ethnicity, body mass index (BMI), insurance type, marital status, patient's home address, highest education achieved, surgery date, and copayments for PT; dates of PT service; active flexion for both the surgical and non-surgical knee; and the Knee Injury and Osteoarthritis Outcome Score (KOOS) assessed preoperatively and at 12-week follow-up. Data were entered into REDCap, a secure web application for building and managing online surveys and databases.

Patients' copayments for PT sessions varied depending on their insurer and plan. Patients insured by Medicaid or standard Medicare plans did not incur a copayment for PT sessions while copayments ranged from \$0 to \$20 for those insured by Medicare replacement plans and from \$25 to \$60 for those insured by private insurers. Distance to the PT office was calculated as the shortest driving distance in kilometers from the patient's home address to PT clinic using Google Maps. Distance was not calculated for patients who reported a post office box as their home address.

Physical therapists who assessed ROM practiced independently from the surgeon who had no role in collecting these data. Active flexion was measured from lateral malleolus to lateral femoral condyle at the knee to greater trochanter using a universal long arm goniometer, which has been shown to have excellent inter- and intrarater reliability.<sup>10</sup> This measurement was obtained while patient was laying supine and instructed to pull their heel toward their buttocks as far as possible.

The Knee Injury and Osteoarthritis Outcome Score (KOOS) is self-administered and assesses five domains: Pain, Symptoms, Function in daily activities (ADL), quality of life (QOL), and Function in Sport and Recreation.<sup>11</sup> Patients completed the KOOS in the clinic immediately prior to TKA and their 12-week follow-up visit. The Function in Sport and Recreation subscale was omitted from analyses of the KOOS as it is the least relevant domain to this population. KOOS subscale scores were transformed to a 0-100 scale, with 0 representing extreme problems and 100 representing no problems.<sup>11</sup> The KOOS has acceptable psychometric properties and a long history of use in knee osteoarthritis research conducted in the US and globally.<sup>12</sup>

## Primary Outcome & Statistical Analysis

The primary outcome was the difference in improvement in active knee flexion from pre-TKA to 12-week follow-up between patients who completed PT (attended 17 PT sessions within a 6-week period) vs did not complete PT. The 12-week follow-up was selected because

improvement in postoperative active knee flexion maximizes 12 weeks after TKA with no significant improvements occurring thereafter,<sup>13</sup> and knee flexion 3 months after TKA is a significant predictor of patient satisfaction 1 year after TKA.<sup>14</sup> In addition, a relatively short (12 weeks) follow-up period should reduce the potential impact of factors other than PT on outcomes, as the typical duration of supervised outpatient PT is 4-8 weeks. Using the proc power module for a two sample *t*-test in SAS/STAT software version 9.4 (SAS Institute, Cary, NC), we calculated that a sample size of 216 patients would be necessary to detect a clinically relevant difference of 5° between groups in the primary outcome, with 80% power and a 5% alpha level. This calculation was based on an assumed standard deviation of 12.3°, which was observed within a similar group of patients not included in the study. Data were analyzed using SAS/STAT software version 9.4 (SAS Institute, Cary, NC). Descriptive statistics were calculated for demographic and baseline characteristics, number of PT sessions attended, active and passive ROM by number of sessions attended, and the cumulative proportion of patients achieving  $\geq 90^\circ$ ,  $\geq 100^\circ$ , and  $\geq 110^\circ$  of active flexion in the operated knee. These thresholds represent the minimally acceptable ( $\geq 90^\circ$ ), satisfactory ( $\geq 100^\circ$ ), and ideal ( $\geq 110^\circ$ ) active knee active flexion goals for patients 6 weeks after TKA. Patients who achieve at least 90° of active flexion should be able to walk on level and sloped surfaces, put on shoes, use the toilet independently, and lift objects.<sup>15</sup> Achieving  $\geq 100^\circ$  active flexion will further allow patients to ascend and descend stairs and sit and rise from a standard chair.<sup>16</sup> Achieving  $\geq 110^\circ$  active flexion will enable patients to sit and rise from a low chair.<sup>16</sup> Knee ROM of at least 120° is required to put on pants and get into and out of a bathtub.<sup>16</sup>

Chi-square tests and multivariable logistic regression analyses were used to evaluate, respectively, univariable and multivariable associations between patient characteristics and PT engagement and completion. To be included in multivariable analyses, a variable required a univariable association with the outcome variable of  $P < .05$ . Analysis of variance with a single degree of freedom linear and quadratic contrasts were performed to investigate the association between number of PT sessions attended and change in ROM and KOOS values, calculated as the value at 12 weeks minus the preoperative value adjusted for preoperative values.

## Results

### Patient Characteristics

Characteristics of the 270 eligible patients are shown in Table 1. Their mean age and BMI were 68.6 years and

**Table 1.** Patient Characteristics.

Characteristic	(n = 270)
Age (years), mean (SD)	68.6 (8.6)
BMI, (kg/m <sup>2</sup> ), mean (SD)	32.5 (5.5)
Sex, % (n)	
Female	67.4 (182)
Male	32.6 (88)
Race, % (n)	
Black	38.9 (105)
White	56.3 (152)
Other	4.8 (13)
Education, % (n)	
High school graduate or less	44.1 (105)
> High school	55.9 (133)
Partner, % (n)	48.7 (129)
Insurance type, % (n)	
Private	35.6 (96)
Medicare	23.7 (64)
Medicare advantage	34.8 (94)
Medicaid	3.7 (10)
Other	2.2 (6)
Distance to PT office, % (n)	
<40 km	86.3 (226)
≥40 km	13.7 (36)
Range of motion, mean (SD)	
Flexion	106.1 (15.0)
Extension	7.2 (5.6)
KOOS, mean (SD)	
Pain	38.9 (19.2)
Symptoms	41.4 (20.8)
ADL	40.3 (20.1)
QOL	21.8 (17.5)

ADL = Function in daily living; KOOS = Knee Injury and Osteoarthritis Outcome Score; PT = physical therapy; QOL = quality of life; SD = standard deviation.

The following variables had missing data: education (n = 32), partner (n = 5), distance to PT office (n = 8), range of motion (n = 16) and KOOS subscales (n = 8-12).

32.5 kg/m<sup>2</sup>, respectively, with most being female (67.4%), white (56.3%), educated beyond high school (55.9%), and unmarried (51.3%). Approximately one third had private insurance (35.6%) and the remaining patients (64.4%) were insured by government and other payers (Medicare/Medicare Advantage/Medicaid/other). Most patients lived within 40 km of the PT clinic (86.3%).

### Number of PT Sessions Attended

Of the 270 patients, 86.7% (n = 234) attended at least two PT sessions at the hospital-affiliated clinic within 6 weeks of TKA ("PT engagement") and, among the 215 engaged patients who completed all PT at the hospital-affiliated facility, 46.5% (n = 100) completed ≥17 sessions within

6 weeks ("PT completion"). Among patients who did not attend PT outside the hospital-affiliated clinic (n = 230), the number of PT sessions attended ranged from 0 to 21 within 6 weeks and from 0 to 35 within 12 weeks of TKA, with a mode of 17 sessions for both follow-up periods (Figure 1). Within 6 weeks of TKA, 15 (6.5%) patients attended zero or one PT sessions, 10 (4.3%) patients two to eight sessions, 86 (37.4%) patients nine to 15 sessions, 101 (43.9%) patients 16-18 sessions, and 18 (7.8%) patients 19-21 sessions. Within 12 weeks of TKA, 12 (5.2%) patients attended zero or one PT session, seven (3.0%) two to eight sessions, 52 (22.6%) 9-15 sessions, 56 (24.3%) 16-18 sessions, 54 (23.5%) 19-22 sessions, and 49 (21.3%) 23-35 sessions.

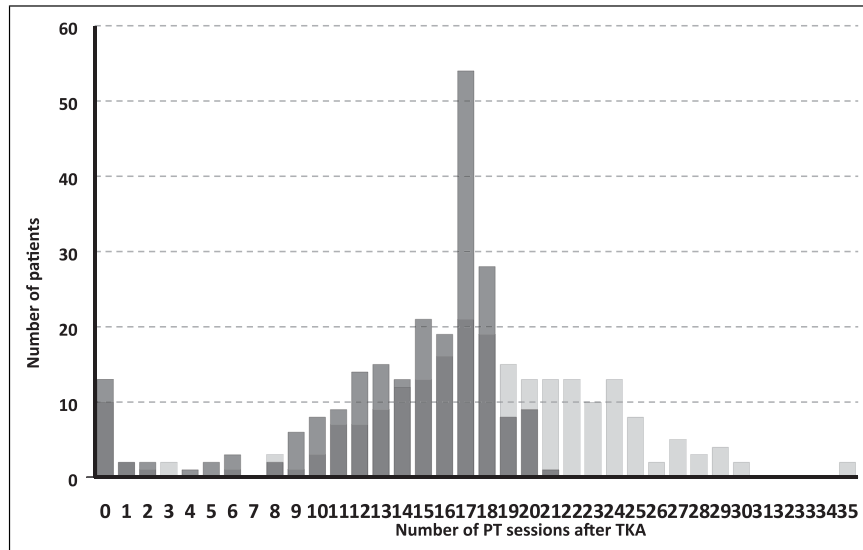
### Predictors of PT Engagement and Completion

In univariable analyses, distance from home to the PT clinic was the only variable significantly associated with PT engagement ( $P = .002$ ; Figure 2). Whereas 90.7% of patients who lived <40 km from the clinic were engaged in PT, this was true for only 66.7% of those who lived ≥40 km from the clinic ( $P < .001$ , Table 2). Race, sex, and partnered status were significantly ( $P < .05$ ) associated with PT completion in univariable analyses (Table 3). In multivariable analyses that included sex, race, and partnered status for PT completion, no variable was significantly associated with PT completion (Table 4).

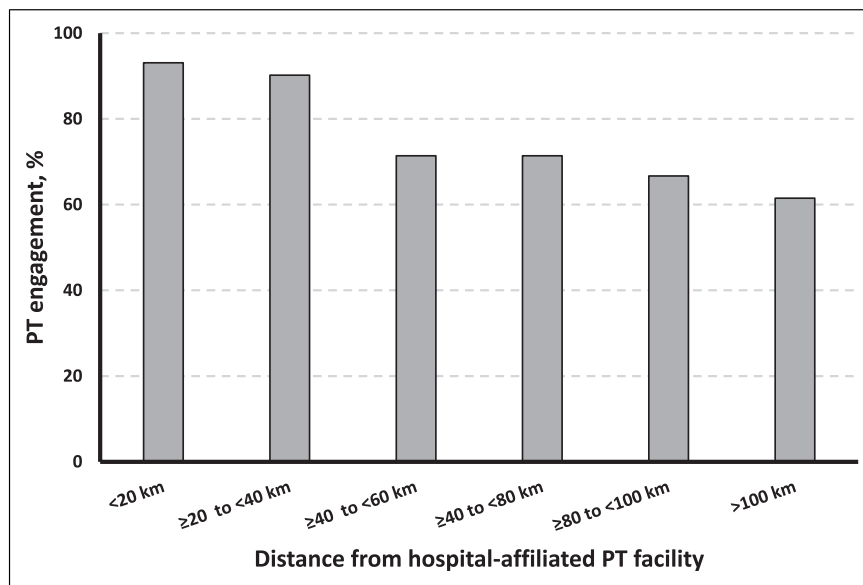
### Relationship Between Number of PT Sessions and Knee ROM

Figure 3 shows the mean active knee flexion assessed at the preoperative visit, first PT session, and last PT session. Patients who completed 10 or more PT sessions within 6 weeks following TKA appear to have achieved roughly similar final mean active flexion values (~110°). Patients who attended 1-5 PT sessions appear to have had higher mean preoperative active knee flexion values than patients who attended 6 or more PT sessions but also had a final mean active knee flexion that fell short of their mean preoperative value. In contrast, patients who attended 6 or more PT sessions achieved a mean final active flexion that was at least as high as their mean preoperative value (except for the patient who attended 21 PT session). As shown in Table 5, there were no statistically significant associations between change from preoperative to final follow-up flexion and extension and number of PT sessions attended.

Figure 4 shows the cumulative percentage of PT engaged patients who achieved active knee flexion of ≥90°, ≥100°, and ≥110° over 12 weeks. By 6 and 12 weeks, respectively, 94.4% and 96.7% of patients had



**Figure 1.** Distribution of number of physical therapy (PT) sessions attended within 6 Weeks (dark gray) and 12 Weeks (light gray) after total knee arthroplasty (TKA) (n = 270).



**Figure 2.** Physical Therapy (PT) Engagement (Attendance of  $\geq 2$  PT Sessions) After Total Knee Arthroplasty (TKA) by Distance from Hospital-affiliated PT Facility (n = 262). Overall Difference in 20-km increments ( $P = .002$ ).

achieved  $\geq 90^\circ$ , 82.5% and 92.1% had achieved  $\geq 100^\circ$ , and 58.1% and 84.2% had achieved  $\geq 110^\circ$  of active flexion. Among the 125 patients who achieved  $\geq 110^\circ$  of active flexion by 6 weeks, 77 continued to attend additional PT sessions after achieving this goal.

Figure 5 shows the cumulative percentage who achieved active knee flexion of  $\geq 90^\circ$ ,  $\geq 100^\circ$ , and  $\geq 110^\circ$  over 6 weeks among patients who completed 16-18 PT sessions within 6 weeks ( $\pm 1$  session from the prescribed 17 sessions). Among this subset of patients, 95.0%, 85.1%, and 56.4%

achieved active flexion of, respectively,  $\geq 90^\circ$ ,  $\geq 100^\circ$ , and  $\geq 110^\circ$  by the end of prescribed PT.

Table 6 shows the relationship between change in KOOS values from baseline to week 12 and number of PT sessions attended after TKA. The magnitude of improvement in KOOS Symptoms, ADL, and QOL subscale scores linearly decreased as the number of PT sessions attended increased with the smallest improvement in KOOS scores seen in the subgroup who attended  $\geq 23$  PT sessions.

**Table 2.** Patient Engagement in and Completion of Physical Therapy (PT) by Patient Characteristics.

Characteristic	PT Engagement (n = 270)	PT Completion (n = 215)
	% (n)	% (n)
Age (years)		
<65	84.3 (59)	50.9 (28)
≥65 to <75	85.8 (115)	49.1 (52)
≥75	90.9 (60)	37.0 (20)
BMI (kg/m <sup>2</sup> )		
<25	84.2 (16)	42.9 (6)
≥25 to <30	87.5 (70)	49.2 (32)
≥30 to <35	85.7 (72)	53.7 (36)
≥35	87.4 (76)	37.7 (26)
Sex		
Female	86.8 (158)	42.5 (62)
Male	86.4 (76)	55.1 (38)
Race		
Black	84.8 (89)	35.4 <sup>b</sup> (28)
White	86.8 (132)	54.0 <sup>a</sup> (67)
Other	100 (13)	41.7 <sup>ab</sup> (5)
Education		
High school graduate or less	88.6 (93)	42.4 (24)
> High school	85.0 (113)	52.4 (55)
Partner		
No	87.5 (119)	39.3 (42)
Yes	85.3 (110)	54.4 (56)
Insurance type		
Private	86.5 (83)	52.0 (40)
Other	86.8 (151)	43.5 (60)
Distance to PT office		
<40 km	90.7 (205)	45.8 (88)
≥40 km	66.7 (24)	44.4 (8)

BMI = body mass index; PT = physical therapy.

The following variables had missing data: education (n = 32), partner (n = 5), and distance to PT office (n = 8).

## Discussion

In this study of a racially heterogeneous group of 270 TKA patients, the only statistically significant predictor of PT engagement was living in closer proximity to the hospital-affiliated PT facility and no variables were statistically significant predictors of PT completion. Patients who attended at least 2 PT visits achieved approximately the same mean active flexion (~110°) at 6 weeks regardless of number of sessions attended. The largest gains in the cumulative percentage of patients who achieved active flexion of ≥110° occurred during post-operative weeks 1-6 with smaller increases in patients achieving this threshold occurring during weeks 7-12. Combined, these findings suggest that not all patients may need to complete prescribed PT after achieving a satisfactory goal of active flexion within 6 weeks and there are diminishing ROM gains for patients who attend

PT past 6 weeks. Supporting this conclusion of diminishing returns with additional PT, patients who attended more PT sessions than prescribed had roughly equal (19-22 sessions) or worse (≥23 sessions) self-reported outcomes at 12-week follow-up.

Consistent with previous studies,<sup>17,18</sup> we found that shorter distance to the PT facility was associated with a higher likelihood of PT engagement. It is unknown whether patients who prematurely discontinued PT at our hospital-affiliated clinic chose to attend PT closer to their home. Patients who travelled a further distance for surgery may live in rural areas with fewer local health resources including PT. Several studies have evaluated the impact of easier access to PT on attendance. A retrospective observational study found that providing no-cost transportation to PT for patients in underserved areas significantly increased attendance at an outpatient private practice PT clinic.<sup>19</sup> Additionally, a randomized clinical

**Table 3.** Univariable Predictors of Physical Therapy Engagement and Completion.

Variable	PT Engagement	P value	PT Completion	P value
Age		.529		.167
<65	1.00		1.00	
≥65 to <75	1.07 (.47 – 2.41)		.93 (.48 – 1.81)	
≥75	1.77 (.61 – 5.14)		.51 (.23 – 1.12)	
Body mass index		.945		.226
<25	1.00		1.00	
≥25 to <30	1.50 (.36 – 6.25)		1.75 (.46 – 6.66)	
≥30 to <35	1.37 (.34 – 5.56)		2.10 (.56 – 7.93)	
≥35	1.51 (.37 – 6.21)		1.07 (.28 – 4.05)	
Sex		.886		.035
Female	1.00		1.00	
Male	.95 (.45 – 2.01)		1.91 (1.05 – 3.50)	
Race		.637		.011
Black	1.00		1.00	
White	1.19 (.58 – 2.42)		2.14 (1.19 – 3.84)	
Education		.436		.143
High school graduate or less	1.00		1.00	
> High school	.74 (.34 – 1.60)		1.56 (.86 – 2.83)	
Partner		.556		.022
No	1.00		1.00	
Yes	.81 (.40 – 1.64)		1.94 (1.10 – 3.43)	
Insurance type		.924		.090
Other	1.00		1.00	
Private	.97 (.46 – 2.02)		1.65 (.93 – 2.96)	
Distance to PT office		.001		.924
<40 km	1.00		1.00	
≥40 km	.21 (.09 – .48)		1.05 (.39 – 2.86)	

PT = physical therapy. Values are expressed as odds ratio (95% confidence interval). The following variables had missing data: Education (n = 24) and partnership (n = 4).

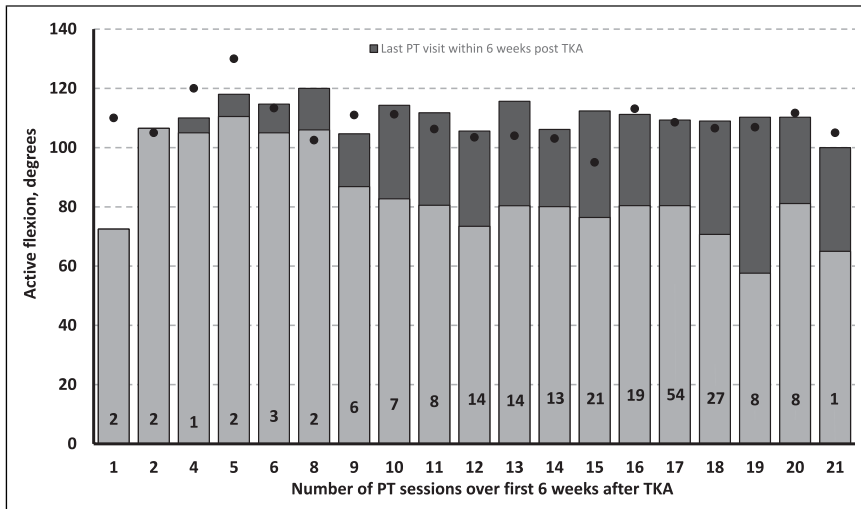
**Table 4.** Multivariable Predictors of Physical Therapy Completion.

	OR (95% CI)	P Value
Sex		.212
Female	1.00	
Male	1.52 (.79 – 2.94)	
Race		.056
Black	1.00	
White	1.81 (.98 – 3.34)	
Partner		.184
No	1.00	
Yes	1.52 (.82 – 2.81)	

CI = confidence interval; OR = odds ratio; PT = physical therapy. The following variables had missing data: partner (n = 4).

trial found that home-based, self-directed rehabilitation was non-inferior to and more cost-effective than hospital-based rehabilitation in patients who underwent uncomplicated TKAs over a 6 month follow-up period.<sup>20</sup>

Early improvement in knee ROM is a focus of out-patient PT because it is an objective outcome that can be reliably measured, is critically related to patients' ability to perform activities of daily living,<sup>16,21</sup> and strongly predicts their degree of satisfaction 6-12 months following TKA.<sup>5,14</sup> In the present study, patients who attended ≥2 PT sessions achieved roughly the same mean active flexion (~110°) regardless of the number of PT sessions attended, suggesting that some patients may have been able to discontinue PT before completing the prescribed 17 sessions. Patients who began PT with a higher active flexion ROM had higher mean preoperative flexion ROM and attended fewer PT visits within 6 weeks. Although patients in this subgroup may have lost flexion after surgery, the fact that they discontinued PT early may indicate that they were satisfied with achieving about 110° of active flexion. As shown in Figure 4, about 40% of patients had achieved active knee flexion ≥110° by week 4 following TKA; it is uncertain whether additional PT sessions would be required for these patients to eventually attain the ≥120° of active flexion required to perform all essential activities of

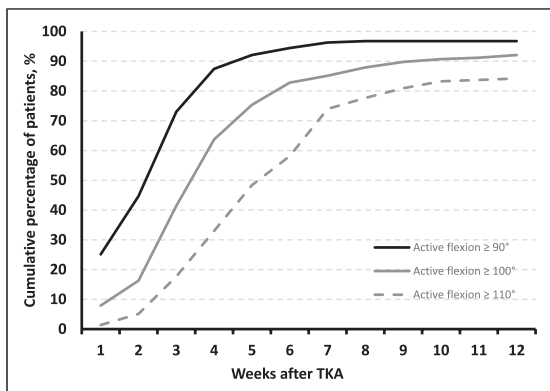


**Figure 3.** Active Knee Flexion Before and 6 Weeks After Total Knee Arthroplasty (TKA) by Number of Physical Therapy (PT) Sessions Attended. The black dot indicates the mean active knee flexion before TKA. The light gray bar is the mean active knee flexion assessed at the first PT session following TKA. The dark gray bar is the mean active flexion assessed at the last PT session attended within 6 weeks after TKA. The number within each bar is the number of patients. A total of 217 patients who attended PT exclusively within the hospital-affiliated clinic were included in this analysis.

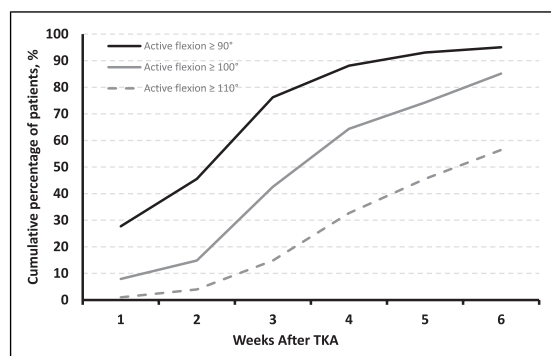
**Table 5.** Change in Range of Motion 12 weeks after TKA (n = 211).

	Number of PT Sessions					Overall	Linear	Quadratic
	9-12 (n = 14)	13-15 (n = 29)	16-18 (n = 50)	19-22 (n = 48)	≥23 (n = 38)	P Value	P Value	P Value
Flexion	4.1 (2.9)	5.7 (2.0)	4.0 (1.5)	5.8 (1.5)	2.6 (1.7)	.657	.698	.416
Extension	-6.3 (.7)	-5.5 (.5)	-5.5 (.4)	-6.2 (.4)	-6.1 (.4)	.667	.890	.309

PT = physical therapy; TKA = total knee arthroplasty. Values shown are least square mean (standard error of the mean). The change in flexion and extension was calculated as the value at 12 weeks minus the preoperative value and was adjusted for preoperative values.



**Figure 4.** Cumulative Percentage of Patients Attaining Active Knee Flexion of  $\geq 90^\circ$ ,  $\geq 100^\circ$ , and  $\geq 110^\circ$  Over 12 Weeks After Total Knee Arthroplasty (TKA). Displayed are data for 215 patients who had  $\geq 2$  physical therapy (PT) sessions and completed PT exclusively at the hospital-affiliated clinic.



**Figure 5.** Cumulative Percentage of Patients Attaining Active Knee Flexion of  $\geq 90^\circ$ ,  $\geq 100^\circ$ , and  $\geq 110^\circ$  Over 6 Weeks After Total Knee Arthroplasty (TKA). Displayed are data for 101 patients who attended 16-18 physical therapy sessions at the hospital-affiliated clinic within 6 weeks of surgery.



**Table 6.** Change in KOOS 12 Weeks after TKA (n = 211).

KOOS subscale	Number of PT Sessions					Overall	Linear	Quadratic
	9-12 (n = 18)	13-15 (n = 34)	16-18 (n = 56)	19-22 (n = 54)	≥23 (n = 49)	P Value	P Value	P Value
Pain	29.5 (5.5, 11)	28.0 (4.0, 21)	26.2 (2.8, 41)	28.1 (3.1, 34)	15.8 (3.5, 27)	.061	.055	.235
Symptoms	30.4 (5.4, 11)	24.5 (3.8, 21)	24.1 (2.7, 42)	28.1 (3.0, 34)	13.3 (3.3, 29)	.001	.029	.356
ADL	34.3 (5.4, 11)	29.3 (3.9, 21)	27.1 (2.8, 41)	29.5 (3.1, 34)	19.0 (3.4, 28)	.087	.030	.671
QOL	36.8 (6.9, 11)	29.4 (5.1, 21)	30.0 (3.6, 42)	31.2 (4.0, 33)	16.7 (4.3, 28)	.057	.031	.480

ADL = Function in daily living; KOOS = Knee Injury and Osteoarthritis Outcome Score; QOL = quality of life; TKA = total knee arthroplasty. Values are least square mean (standard error of the mean, n). The change in KOOS was calculated as the score at 12 weeks minus the preoperative value and was adjusted for preoperative values.

daily living. The increase in the cumulative percentage of patients who achieved active flexion of  $\geq 110^\circ$  was highest during weeks 1-6 and lower during weeks 7-12, suggesting that there are diminishing benefits in terms of improving ROM with additional PT beyond 6 weeks for some patients. Among the 125 patients who achieved  $\geq 110^\circ$  of active flexion by 6 weeks, 77 continued to attend additional PT sessions after achieving this goal. Some patients who achieved  $\geq 110^\circ$  active flexion by 6 weeks and continued to attend PT may have desired a higher ROM that would allow them to return to sports, physical work, or other activities that required a higher degree of active flexion. It is also likely that some patients continued PT beyond what was necessary to achieve their desired level of physical function.

The present study found that patients who attended 9-22 PT sessions experienced roughly similar improvements in ROM which were not significantly associated with number of PT sessions attended. The relative importance of preoperative ROM in determining ROM following TKA is unclear with some studies reporting that preoperative ROM is an important predictor of postoperative ROM<sup>15,22,23</sup> and other studies finding more important predictors of postoperative ROM than preoperative ROM.<sup>24,25</sup> In fact, the relationship between preoperative and postoperative ROM following TKA may be nonlinear with patients with the highest preoperative ROM tending to experience the least improvement ROM and those with the worst preoperative ROM tending to gain the most ROM.<sup>25,26</sup>

In the present study, improvement in KOOS Symptoms, ADL, and QOL subscales declined with the number of PT sessions attended. However, changes in these KOOS subscales were similar for patients who attended 9-12, 13-15, and 16-18, and 19-22 PT sessions and considerably lower for those who attended  $\geq 23$  sessions. These findings suggest that attending PT sessions beyond (19-22 session) and well-beyond ( $\geq 23$  sessions) the prescribed 16-18 PT sessions does not yield significant gains in patient-reported outcomes and may be a waste of resources, and that attending the highest number of PT sessions after TKA may

indicate poor long-term outcomes in patients. In our hospital-affiliated facility, the physical therapist has sole discretion to recommend additional PT sessions beyond the 17-session protocol. Understanding therapists' rationale for recommending additional sessions and their assessment of the effectiveness of additional intervention will be important in creating guidelines for prescribing PT following TKA.

### Limitations & Strength

The main limitations of this study are its retrospective nature, relatively small sample treated at a single private academic hospital, restriction to patients with planned same-day-discharge, and short duration of follow-up. Because patients were treated at a single urban setting located in a Southern state, findings cannot be generalized to other settings within or outside of this region. In addition, findings cannot be generalized to patients ineligible for same-day-discharge, who are often older and have more comorbidities. Although the sample was racially diverse, most patients were insured by Medicare and private insurance and a smaller proportion by Medicaid; thus, findings may not generalize to economically disadvantaged patients. Because we did not have access to data regarding the number of PT sessions attended at unaffiliated PT providers, our analysis of the relationship between number of PT sessions attended and outcomes excluded these patients and included only patients who completed PT at the clinic-associated facility. The advantage of studying patients who underwent PT at the same clinic is that these patients were likely to have experienced consistency in PT treatment and ROM measurement. Because patient copayment amounts varied depending on type of insurance and health plan, the copayment amount may have influenced PT attendance; unfortunately, due to restrictions in access to these data, we were unable to investigate this relationship. Finally, we had no access to information about why patients stopped attending PT before completing their prescribed course or, conversely, attended more PT sessions prescribed.

The present study was conducted at a facility that utilized outpatient PT as the standard of care for rehabilitation after TKA. The popularity of home-based PT and self-directed web-based PT has increased based on strong evidence that these PT modalities are non-inferior to and more cost effective than outpatient PT for selected, uncomplicated TKA patients.<sup>27-30</sup> Despite a shift towards home-based and web-based PT, approximately 34% of primary TKA patients are not deemed appropriate for self-directed PT and one third of TKA patients who initiate self-directed PT switch to outpatient PT due to lack of progress, noncompliance, or patient preference.<sup>31</sup> Although outpatient PT may be reconsidered as standard of care following primary TKA, a substantial proportion of TKA patients are likely to still require this PT modality and our study results are relevant to these patients,

## Conclusion

In this study, patients achieved roughly the same mean degree of active flexion within 6 weeks regardless of number of PT sessions attended, with 40% of patients achieving the satisfactory threshold of  $\geq 110^\circ$  before 6 weeks. Additionally, patients who attended PT beyond the prescribed 16-18 sessions had roughly equivalent (19-22 sessions) or worse patient-reported outcomes at 12-week follow-up, suggesting that a subgroup of TKA patients may be receiving additional PT without meaningful improvements in clinical outcomes. Randomized clinical trials are needed to establish more definitively the relationship between PT “dose” and outcomes following TKA. Additional studies are also needed to determine which patients would benefit most from less resource intensive postoperative PT modalities, such as self-directed Web-based PT. Such studies should assess patient expectations for recovery after TKA and document patient and provider reasons for continuing or discontinuing PT.

## Authors' Contribution

GB: Conceptualization; Data curation; Investigation Methodology; Roles/Writing – original draft; Writing – review & editing. ZA: Conceptualization; Data curation; Investigation Methodology; Roles/Writing – original draft; Writing – review & editing. MD: Conceptualization; Data curation; Investigation Methodology; Roles/Writing – original draft; Writing – review & editing. JD: Conceptualization; Data curation; Investigation Methodology; Roles/Writing – original draft; Writing – review & editing. CL: Conceptualization; Data curation; Formal analysis; Investigation Methodology Roles/Writing – original draft; Writing – review & editing. AB: Supervision; Validation; Visualization; Roles/Writing – original draft; Writing – review & editing. VD: Data curation; Supervision; Validation; Writing – review & editing.

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## Ethical Statement

### Ethical Approval

Institutional review board approval was obtained for this study.

## ORCID iD

Gregory Benes  <https://orcid.org/0000-0002-2527-2278>

## Supplemental Material

Supplemental material for this article is available online.

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