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A Comparison of Patient-Reported and Measured Range of Motion in a Cohort of Total Knee Replacement Patients

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Abstract

Range of motion (ROM) is an important component of the assessment of total knee replacement (TKR) outcome. We compared patient-reported versus clinically observed ROM in a prospective cohort. Clinically observed ROM was measured using a goniometer by a trained research assistant. Self-reported ROM was estimated using a set of lateral knee photographs depicting varying levels of flexion and extension. All measures were taken pre-operatively, three, and six months postoperatively. We found statistically significant associations between self-reported ROM and clinically observed ROM for flexion and extension (all $P < 0.001$). We dichotomized flexion at 90 degrees and found that self-report had a specificity of 94% and sensitivity of 65%. We conclude that patient-reported ROM may be a useful outcome measure for TKR.

Keywords

total knee replacement; self-reported outcomes; range of motion; knee osteoarthritis; rehabilitation

Introduction

Total knee replacement (TKR) is commonly utilized to improve pain and function in persons with advanced knee osteoarthritis (OA), with over 600,000 procedures performed annually in the US.[1] Approximately 97% of TKRs are performed for knee osteoarthritis.[2] The procedure is remarkably successful, with about 80% of TKR recipients experiencing substantial pain relief and functional improvement.[3, 4]

Advanced knee OA is typically associated with reduced knee range of motion (ROM), which in turn heightens the disability and functional limitations of knee OA.[5–9] Individuals who cannot flex greater than 90 degrees or extend to a neutral position may experience difficulty with routine activities such as rising from chairs or walking. One of the goals of TKR is to restore ROM to a functional range.[10] Given its functional importance,

knee ROM is a crucial component of pre- and postoperative assessment in patients undergoing TKR. In fact, ROM is an important component of the American Knee Society Score.[11] One study of patients undergoing TKR found that both preoperative and 12-month knee flexion had modest associations with 12-month function. In addition, at 12 months patients with less than 95 degrees of flexion had significantly worse function than patients with greater than 95 degrees of flexion.[12]

Traditionally, ROM is measured by a clinician or trained researcher. The need for direct measurement renders assessment of ROM more logistically complex and resource intensive than assessment of pain and health status, which can be elicited with self-report measures administered by phone or mail. One approach to this problem is patient self-assessment of ROM. Recently Gioe et. al. developed a method that presents patients a set of lateral knee photographs depicting varying levels of flexion and extension and asks patients to select the photographs that most closely resemble their motion.[13] The authors compared this patient self-reported ROM with physician measurements in a cross sectional study of patients at least one year post-TKR and concluded that patient-reported ROM was sufficiently accurate for use in long-term surveillance after TKR.[13]

A study by Khanna and colleagues also concluded that knee ROM could be accurately reported by patients based on photographs.[14] This study also reported that patient self-assessment using a goniometer was not superior to assessment with photographs. Neither Khanna et. al. nor Gioe et. al. compared patient-reported ROM before and after TKR.

In this study, we aimed to compare this self-reported method of assessing flexion and extension with clinical measurement before and after TKR. Our goal was to validate the findings of Gioe et. al. and Khanna et. al. in an independent sample and to extend these findings to a prospective cohort permitting evaluation of change in ROM over time.

Materials and Methods

Sample

This study was conducted as part of a prospective cohort study of consecutive patients undergoing TKR by five orthopedic surgeons at a tertiary medical center. Patients were enrolled between August 2010 and May 2011. Eligible patients were aged 40 years or older, had a primary diagnosis of OA and spoke English. Patients with a diagnosis of inflammatory arthritis, those who lived in a nursing home, and those with plans for additional elective surgery within 6 months were excluded. A research assistant screened surgeons' schedules for eligible patients, who were then invited to participate. This study was approved by the Institutional Review Board.

Data collection

Subjects were assessed pre-operatively at baseline and at 3 and 6 months postoperatively. Baseline visits were completed in person. Patients were given the option to complete the post-operative visits in person or to mail in a study survey. In-person visits included a physical exam performed by a trained research assistant (RA), including measurement of active ROM using a goniometer. Research assistants underwent intensive knee examination

training either by the lead Physical Therapist or by the study Co-Investigator, a Rheumatologist. Approval was required prior to permitting the RA's independent examination of the patient, and RA competency was evaluated and documented annually. We did not have access to an examining table, so flexion measurements were taken with patients seated in a portable wheelchair and extension measurements were obtained with patients standing. We examined feasibility, reliability, and comfort using various types of chairs for persons of different height and body habitus. We found that a portable wheelchair was best in terms of standardization as well as the fidelity of the data, though we found no discernible differences between the various types of chairs. The seat of the wheelchair was approximately 18 inches high and 18 inches deep and was not cushioned. As a part of the study questionnaires, patients were asked to self-report flexion and extension on their operated knee using the method of Gioe et. al. in which study participants were presented with pictures of knees positioned at varying levels of flexion and extension.[13] The pictures show the knees in seated position. Six pictures show flexion ranging from 80 degrees to >120 degrees in increments of 10 degrees. Four pictures show extension ranging from completely straight to >20 degrees from straight. The questionnaires also assessed demographic information as well as level of pain and function using the Western Ontario and McMaster Universities Arthritis Index (WOMAC).[15]

Statistical analysis

We compared demographic and clinical features of patients who completed in-person versus mail-in follow-up visits to ensure that there were no differences in the two groups. We expressed flexion as degrees of flexion beyond neutral and extension as the degrees of flexion contracture (failure to reach neutral). Thus, greater 'extension' reported in this paper represents greater contracture and higher numbers reflect worse status. We examined associations between clinically observed ROM as measured by the RA and self-reported ROM as captured in the photographs. First, we tested whether mean RA-measured ROM differed by patient-reported category using ANOVA. Then we modeled patient-reported ROM as an ordinal variable to investigate for linear trend.

We considered poor flexion to be a measurement of less than 90 degrees.[12, 16] We dichotomized measured flexion as less than or greater than 90 degrees and compared this to the self-reported category to determine the sensitivity and specificity of patient self-assessment of poor flexion. Confidence intervals were adjusted to account for clustering within patients. [17]

For both flexion and extension we grouped patients based on change from baseline in self-reported ROM into categories of improved, no change, and worsened. For flexion, improvement was defined as having a higher self-reported category (greater flexion) at follow-up as compared to baseline, while for extension a lower self-reported category (less contracture) was considered improvement. We evaluated the mean change in measured flexion and extension for each of the three categories. We did this separately at 3 and 6 months.

Data were collected and managed using REDCap electronic data capture tools hosted by Partners HealthCare Research Computing, Enterprise Research Infrastructure & Services (ERIS) group. [18] All analyses were conducted in SAS v9.3 (SAS Inc., Carry, NC).

Results

Baseline cohort characteristics

One hundred and sixteen patients signed consent and were enrolled into the study. For the purposes of this study, we excluded 3 patients who underwent simultaneous bilateral TKR and 1 patient who did not complete a baseline questionnaire; thus, 112 patients were included in the analysis. Among these individuals all patients completed a baseline questionnaire (100 with both objective ROM measurement by a research assistant as well as self-rated ROM), 98 completed a 3-month questionnaire (62 with both objective ROM measurement and self-rated ROM), and 94 completed a 6-month questionnaire (53 with objective ROM measurement and self-rated ROM). The mean age of the cohort at baseline was 64.8 years (SD 8.9), 52% were female, and 91% were White (Table 1). The mean pre-operative WOMAC pain and function scores were 42.6 (SD 17.7) and 44.2 (SD 15.4) respectively (scaled from 0–100; 100 worst).

Comparison of patients with and without ROM measured

Patients with objective ROM measurements at follow-up (in-person visits) were similar to patients without objective ROM measurements with respect to age, WOMAC (at baseline and at the follow-up visit when ROM was assessed), and self-rated flexion and extension. Baseline objectively measured ROM was also comparable. For example, patients with objectively measured ROM at month 3 had a mean baseline flexion of 110.2 (SD 13.2) compared to a mean baseline flexion of 109.2 (SD 11.6) in the group that did not have ROM objectively measured at month 3 (please refer to the supplementary appendix for more information).

ROM by visit

We focused our analysis on patients with both self-rated and objectively measured ROM: $n=100$ at baseline, $n=62$ at month 3 and $n=53$ at month 6. The mean objectively measured extension was 8 degrees at baseline (SD 6.3), 7 degrees at month 3 (SD 4.5), and 4.5 degrees at month 6 (SD 4.4). At baseline, 41% of patients reported the ability to completely straighten their knee. This rose to 63% at month 3 and 77% at month 6. The mean objectively measured flexion was 109.9 degrees at baseline (SD 12.6), 105.4 degrees at month 3 (SD 13.6), and 106.9 degrees at month 6 (SD 11.1). At baseline, 15% of patients reported the ability to bend their knee less than 90 degrees. This was 16% at month 3 and dropped to 4% at month 6 (Table 2).

Association between measured and self-reported ROM

At baseline, the average mean measured extension was 5 degrees (SD 4.2) for patients who reported the ability to fully extend their leg; for those reporting extension (flexion contracture) between 5 and 10 degrees, mean measured extension was 9.8 degrees (SD 6.1); for those reporting extension between 11 and 20 degrees, mean measured extension was

10.1 degrees (SD 6.7); and for those reporting extension greater than 20 degrees, mean measured extension was 15 degrees (SD 6.1) ($p<0.001$) (Figure 1). These findings were similar at 3 and 6 months post-TKR, although only 1 patient reported extension greater than 10 degrees. There was a linear association with objective measurement of extension and self-report category: for each increase in self-report category, measured extension increased on average by 3 degrees ($p<0.001$). These significant associations persisted across all time points.

There was also an association between self-reported flexion and clinical measurement. Preoperatively, those patients rating flexion the lowest had the lowest mean measured flexion (96 degrees (SD 12.1)) while those patients rating flexion the highest also had the highest mean measured flexion (116 degrees (SD 11.3)) (Figure 2). This association was statistically significant in an ANOVA model ($p<0.001$). There was a similar trend post-TKR with patients with poor self-reported flexion having poor measured flexion, though there were some differences in the association between self-report and measurement by time point. This statistically significant association remained when self-report category was included as a linear rather than categorical predictor in the ANOVA model. At baseline each increase in category was associated with an increase in measured extension of 4.0 degrees ($p<0.001$); at 3 months post-TKR this increase in extension was 7.5 degrees ($p<0.001$); at 6 months post-TKR this increase in extension was 5.6 degrees ($p<0.001$).

Sensitivity and specificity of self-report

Fifteen of 23 patient visits with poor objectively measured flexion (<90 degrees) also self-reported poor flexion (90 degrees or less) for a sensitivity of 65% (95% CI: 0.44, .86). Similarly, 179 of 191 patient visits without poor flexion (>90 degrees on objective measure) did not self-report poor flexion (to 100° or higher) for a specificity of 94% (95% CI: 0.90, 0.97) (Table 3). Of 187 patients self-reporting adequate flexion (to 100° or higher), 179 did not have poor flexion (>90 degrees) on objective measure for a negative predictive value of 95.7%. We performed a similar analysis using a cut-off point of 95 degrees between poor and good flexion and achieved similar results (data not shown).

Change in ROM over time

Twenty patients rated extension as “straight” at both baseline and 3 months; the average change in measured extension for these 20 patients was -1 degree. In general, patients that self-reported improvement (follow-up category better than baseline category) tended to show improvement in measured ROM, and patients that self-reported worsening (follow-up category worse than baseline category) tended to show worsening in measured ROM (Figures 3 and 4).

Discussion

We compared clinical measurement of flexion and extension with the self-reported method developed by Gioe et. al. in a cohort of patients undergoing primary TKR. [13] We found a statistically significant association between objective measurement and self-report for both flexion and extension at each time point. We also found that patients who self-reported

improvement tended to show improvement in measured ROM, and patients who self-reported worsening tended to show worsening in measured ROM. We dichotomized flexion at 90 degrees to identify patients with poor flexion and found that self-report had high specificity; 94% of patients that had adequate flexion indicated such on self-report.

One of the earliest studies of patient-reported ROM after TKR was conducted by McGrory et al. among a cohort of 83 post-TKR patients, who were, on average, between 1 and 5 years post-surgery.[19] Patients received 5 diagrams depicting knee flexion between 0 degrees and 120 degrees. The study found significant differences between patient- and clinician-reported ROM.

However, more recent studies by Gioe et. al. and Khanna et. al. have found that patients can accurately estimate ROM when presented with photographs in 10 degree or 5 degree increments, respectively.[13, 14] Gioe et. al. found small differences in patient-reported vs. physician-recorded ROM in a cohort of patients at a minimum of 1 year post-TKR; the average difference in extension was 1.6 degrees and the average difference in flexion was 1.5 degrees. Patients tended to overestimate both measures in self-report. In another sample of patients who had undergone TKR, Khanna et. al. also found that the difference between measurement and patient self-report was not clinically important.[14]

Our study examined the association between patient-reported and measured ROM at 3 and 6 months post-TKR and confirmed what other studies have demonstrated at longer follow-up periods: there is a strong, though imperfect, association between self-reported and objectively measured ROM.[13, 14] Self-report is especially useful in confirming adequate flexion: the negative predictive value of 95.7% indicates that patients that reported adequate flexion (to 100 degrees or higher) almost always had adequate measured flexion.

None of the previous studies evaluating the association between ROM measurement and self-report examined change in ROM over time. We found that, on average, patient self-report of improvement, worsening or stable motion was reflected in clinically measured change in ROM.

Results of this study should be interpreted in the context of the study design. Our findings are based on a sample in one tertiary medical center. The results may not be generalizable to other centers, though they are comparable to results found in similar studies. [13, 14] This was a pilot study in preparation for a larger randomized control trial, consequently there were no formal sample size or power calculations. The research assistant did not have access to an examination table. Flexion measurements were taken with patients seated in a standardized chair and extension measurements were obtained with patients standing. Studies have shown moderate to high intra- and inter-rater reliability for goniometric measurement of knee ROM, though inter-rater agreement tends to be lower and it is generally recommended that the same person take all measurements when assessing ROM. [20–22] We had four different research assistants over the course of our study, which may have conferred additional variability in ROM measurement. This is especially important in our evaluation of change in ROM over time in the same individuals: we cannot be certain that each measurement was made by the same research assistant. As these factors would

tend to increase variability, they would bias our results toward more modest associations. Patients were given the option to complete follow-up visits in the clinic or over the phone. While the majority of patients completed follow-up questionnaires (88% at Month 3 and 84% at Month 6), approximately half of the cohort completed follow-up visits in person and thus had ROM measured. While patients with objectively measured ROM at follow-up (in-person follow-up visits) were similar to patients without objectively measured ROM at follow-up in terms of measured covariates, including self-reported ROM, it is possible that the groups differed in terms of unmeasured covariates or in terms of objectively measured ROM. It is possible that the association between self-report and objectively measured ROM is different in the subset of patients not returning for in-person visits. This could bias the results in either direction, since we cannot be sure whether self-report is more or less accurate in this subgroup.

We conclude that our data support the use of patient self-reported ROM as an outcome measurement for TKR when clinical ROM measurement is difficult to obtain. Self-report is particularly effective (>90% specificity) in confirming adequate flexion.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Measured Degrees of Extension by Self-Report Category

This graph shows objectively measured extension versus patient self-report categories (straight, 5–10 degrees, 11–20 degrees, or greater than 20 degrees) at each time point (baseline, 3, and 6 months postoperatively). The number of patients reporting flexion in each category is noted on the x-axis.

Figure 2. Objectively Measured Degrees of Flexion by Self-Report Category

This graph shows objectively measured flexion versus patient self-report categories (80 degrees, 90 degrees, 100 degrees, 110 degrees, 120 degrees, or greater than 120 degrees) at each time point (baseline, 3, and 6 months postoperatively). The number of patients reporting flexion in each category is noted on the x-axis.

Figure 3. Change in Objectively Measured Extension by Change in Self-Report Category

This graph shows the change in objectively measured extension from baseline versus patient self-report categories (improve, no change, worsen) at 3 and 6 months postoperatively. The number of patients in each category is noted on the x-axis.

Figure 4. Change in Objectively Measured Flexion by Change in Self-Report Category

This graph shows the change in objectively measured flexion from baseline versus patient self-report categories (improve, no change, worsen) at 3 and 6 months postoperatively. The number of patients in each category is noted on the x-axis.

Table 1

Baseline Characteristics of Cohort

Characteristic	Statistic
Mean Age (SD)	64.8 (8.9)
Mean BMI (SD)	31.2 (6.5)
Sex, n (%)	
Male	54 (48.2%)
Female	58 (51.8%)
Race, n (%)	
Non-White	10 (9.1%)
White	100 (90.9%)
Surgeon, n (%)	
1	22 (19.6%)
2	6 (5.4%)
3	17 (15.2%)
4	47 (42.0%)
5	20 (17.9%)
Mean WOMAC Pain ^I (SD)	42.6 (17.7)
Mean WOMAC Function ^I (SD)	44.2 (15.4)

^I Scaled from 0–100; 100 is worst

Table 2

Objectively measured and Self Report ROM by Visit

	Baseline n=100	Month 3 n=62	Month 6 n=53
Objectively measured extension (mean, SD)*	8.3 (6.3)	7.0 (4.5)	4.5 (4.4)
Objectively measured flexion (mean, SD)	109.9 (12.6)	105.4 (13.6)	106.9 (11.1)
Self-Reported Extension*			
Completely straight	41 (41.0%)	39 (62.9%)	40 (76.9%)
5–10°	34 (34.0%)	23 (37.1%)	11 (21.2%)
11–20°	14 (14.0%)	0 (0.0%)	0 (0.0%)
> 20°	11 (11.0%)	0 (0.0%)	1 (1.9%)
Self-Reported Flexion			
80°	7 (7.1%)	1 (1.6%)	1 (1.9%)
90°	8 (8.1%)	9 (14.5%)	1 (1.9%)
100°	11 (11.1%)	6 (9.7%)	5 (9.4%)
110°	19 (19.2%)	18 (29.0%)	14 (26.4%)
120°	29 (29.3%)	20 (32.3%)	18 (34.0%)
More than 120°	25 (25.3%)	8 (12.9%)	14 (26.4%)

* extension measured as degrees of contracture (failure to achieve neutral)

Table 3

Sensitivity and Specifity of Self-Report of flexion 90 as compared with objectively measured flexion 90

		Objectively Measured Flexion		
		90°	>90°	Total
Self-Report	To 90° or lower	15	12	27
	To 100° or higher	8	179	187
Total		23	191	214
Sensitivity 65.2% (44.1%, 86.4%)		Predictive Value+ 55.6% (31.2%, 80.0%)		
Specificity 93.7% (90.3%, 97.1%)		Predictive Value- 95.7% (74.8%, 100%)		