Journal of Orthopaedic Surgery 2005;13(2):131-138

The effect of total knee arthroplasty on joint movement during functional activities and joint range of motion with particular regard to higher flexion users

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ABSTRACT

Purpose. To evaluate active and functional knee excursion of patients before and after total knee arthroplasty (TKA) and to determine whether TKA restores quality of life related to functional activities of daily living.
Methods. Electrogoniometry was used to measure the functional movement of the knee during 11 activities of daily living in 50 patients who underwent TKA. These data were compared with the patient's active range of motion and quality-of-life scores.
Results. A cut-off point existed between loss and gain in flexion at between 90 and 95 degrees of preoperative active flexion. Two thirds of patients had preoperative flexion of more than 90 degrees, 83% of them had reduced flexion postoperatively. The remaining one third had preoperative flexion of 90 degrees or less, 85% of them had improved flexion postoperatively. A similar pattern of loss and gain occurred for functional movement of the knee. Reduced functional range was associated with significantly reduced physical quality of life compared with age-matched healthy subjects.
Conclusion. Although TKA offers excellent pain relief and contributes to the overall well-being of the patient, these results suggest that it also leads to a reduced range of active and functional motion in the majority of patients. This is associated with a lower-than-normal physical quality of life. The design of implants and rehabilitation programmes should be reconsidered so that better range of motion and quality of life can be achieved for patients.

***Key words:** activities of daily living; arthroplasty, replacement, knee; movement; quality of life; range of motion, articular; treatment outcome*

INTRODUCTION

Total knee arthroplasty (TKA) has been established as a valuable procedure for the management of patients with disabling knee osteoarthritis.[1,2] The goal of TKA is to provide the best possible outcome for the patient.[3]

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It is performed primarily to relieve the pain and limitation in knee movement caused by arthritis.[4] A number of studies have confirmed that pain is considerably reduced following TKA for most patients. This leads to improved quality of life and greater general mobility.[1,2,5] Nonetheless, the relationship between joint range of motion (ROM)—joint movement during functional activities—and quality of life has been explored with less rigour.

Joint ROM, measured either passively or actively on a couch, is considered an important outcome measure and is included in many knee scoring systems.[5] Arthritis can limit joint motion at one or both extremes of range.[6] The obstacles to extension are nearly always eliminated or reduced after surgery.[7] Surgery can also remove, wholly or partly, the pathological obstacles to flexion, but these may be replaced by mechanical obstacles inherent in the design of the prostheses or tension in the soft tissues.[6] A review of 724 replaced knees indicated that nearly one half could not be flexed beyond 90° at one-year follow-up, and the number of knees that could flex beyond 110° fell postoperatively.[6] Postoperative flexion depended partly on preoperative flexion and partly on the prosthesis used, but the correlation between them was weak and much individual variation remained unexplained.

In a multicentre trial involving 621 patients with 2-year follow-up, patients were divided into 3 groups based on preoperative ROM (≤90°, 91°–105°, and >105°).[3] The mean postoperative ROM was 107°. All postoperative results tended to be within a predictable range—a single range to which all the preoperative values migrated. As a result, the group with low preoperative ROM (≤90°) improved the most. No other patient characteristics showed a significant correlation with the flexion outcome.[3] A more recent review of the literature related to knee flexion following TKA identified 13 papers that dealt with this issue.[8] Although the papers were somewhat contradictory, it was concluded that knees with good preoperative flexion had better final flexion but also lost some flexion, whereas those with poor preoperative flexion gained flexion. The preoperative ROM did not strongly predict the postoperative ROM when applied to the whole group of TKA patients.[8]

The World Health Organization has indicated that good postoperative ROM should not be presumed to be associated with improved quality of life or functional motion of the knee during daily activities.[9,10] A study to determine which functional activities were important to patients following TKA indicated that approximately 50% to 75% of them found stretching, strengthening exercises, kneeling, and gardening difficult and that these activities were important and prevalent for them.[11] They concluded that improvements in knee function following arthroplasty were still needed to allow patients to do activities that they considered important.

In a series of studies,[12–16] our research group has used a system of flexible electrogoniometry[15,16] to scientifically record the angular displacement of the knee during a range of functional activities in both TKA patients[13,14] and normal older adults.[12] These studies explored the impact of TKA on functional ROM, and the extent to which normal function was restored postoperatively. The results indicated that >90° flexion of the knee was required for many daily functional activities, and that there had been little general improvement in knee joint motion in such activities for up to 2 years following TKA.[14]

The literature suggests that knee flexion of >90° may be limited following surgery, and those with higher levels of flexion may lose flexion following surgery. Patients who wish to do activities that require knee flexion of >90° may not achieve this with TKA. Limited postoperative flexion may therefore affect their quality of life and satisfaction with the surgical outcome. These issues have not been explored within a single group of patients.

This study was designed to address several questions: at what level of preoperative ROM do patients cease to gain postoperative ROM? What is the association between preoperative flexion and postoperative loss or gain of knee flexion? Are these effects replicated in functional ROM used by TKA patients? Do ROM data reflect quality of life?

MATERIALS AND METHODS

All patients who underwent unilateral primary TKA due to osteoarthritis by one of the 2 consultant orthopaedic surgeons in Princess Margaret Rose Orthopaedic Hospital between May 1997 and June 1998 were considered for inclusion. The study was approved by the ethics committee of Lothian Health. Of 93 patients reviewed, 32 were excluded for a variety of reasons: inflammatory polyarthritis (n=7), hip osteoarthritis and lower-limb disorders causing abnormal gait or significant pain (n=8), medically unsuitable (n=8), neurological conditions affecting movement (n=3), and inability to give informed consent or medically unfit for surgery (n=6). Informed consent was obtained from 50 (24 women and 26 men, 82%) of the 61 patients who satisfied the inclusion criteria. Patients were operated on by one of the 2 consultant orthopaedic surgeons (consultant A, n=33;

Table 1
11 functional activities of daily living

1	Level walking
2	Ascending a slope (5°)
3	Descending a slope (5°)
4	Ascending stairs (165 mm riser, 280 mm tread)
5	Descending stairs (165 mm riser, 280 mm tread)
6	Sitting down on a low chair (380 mm high)
7	Standing up from a low chair (380 mm high)
8	Sitting down on a standard chair (460 mm high)
9	Standing up from a standard chair (460 mm high)
10	Into a bath (from standing alongside, stepping in, to sitting down; 590 mm high)
11	Out of a bath (from sitting, standing up, stepping out, to standing alongside; 590 mm high)

consultant B, n=17) and all received a rotating platform low contact stress knee replacement (DePuy International, Leeds, UK). The mean age of patients was 70 years (standard deviation, [SD] 9.2; range, 48–90 years), mean weight 81 kg (SD, 12.4; range, 48–108 kg), and mean height 1.64 m (SD, 0.07; range, 1.5–1.85 m).

All tests were carried out in the out-patient clinic by one research physiotherapist. Patients were assessed on 2 occasions: up to 4 weeks preoperatively and 18 to 24 months postoperatively. Eight patients were lost to follow up following the first assessment, thus 42 patients were assessed on 2 occasions. Two flexible electrogoniometers (M180; Penny and Giles, Blackwood, Gwent, UK) were used to measure the flexion-extension angle of the knees during 11 functional activities of daily living (Table 1) carried out in a circuit at the hospital. All activities were performed at the subject's self-selected speed (free speed). Details of the methodology have previously been published.[11–15] For each of the 11 functional activities, a single cycle of the left and right legs were identified from the data. The minimum and maximum knee joint angle for each knee was determined for each functional activity. The excursion of the joint during all 11 functional activities was calculated by subtracting the minimum value used in any of the 11 tasks from the maximum value. This excursion value indicated the amount of free knee-joint angulation during the portfolio of functional activities.

The flexion-extension angle at the end of active flexion and at the end of active extension of both knees was measured by an experienced senior physiotherapist with the subject lying supine. A standard clinical manual protractor goniometer was used and the active excursion was calculated. Patients were asked to complete a SF 36 general health questionnaire to assess their quality of life and to rate the pain they experienced from the affected knee on a visual analogue scale. All measurements were taken within a period of approximately 90 minutes. Differences were considered statistically significant at a p value of <0.05.

RESULTS

Table 2 indicates the mean and SD of pre- and post-operative ranges of active and functional knee joint motion for the affected knee. The mean value for active extension (flexion contracture) fell from 5.7° preoperatively to 0.8° postoperatively. This indicates that all flexion contracture was eliminated after surgery. Meanwhile, mean active flexion fell from 104.3° to 96.9°, with a reduction of 7.4°. Both changes were statistically significant. However, mean active excursion (ie the change in angle achieved by the joint) was only slightly reduced by 2.5° and was not significant. Surgery shifted the active range by approximately 6° but did not significantly expand it. Functional flexion and excursion were not significantly altered by surgery. Functional extension significantly decreased by 1.6°. There was a slight difference in findings between the active and functional data because the active values were recorded using anatomical landmarks with the patient lying supine, whereas the functional ranges were assessed using relative angles between the long axis of the limb segments with the patient standing. The active data therefore included the effect of the flexion contracture, whereas the functional data did not. The active data might also be affected by changes to the anatomical landmarks during surgery, whereas the functional data were not. Regardless of the method used to define the joint angle, the excursion of the joint was compatible between the active and functional sets of data because this was the relative change in angle, and was not affected by the absolute values of the data. Therefore, in subsequent analysis it was appropriate to look at the excursion of the joint rather than the absolute values of flexion or extension. It is sobering to note that postoperative patients had only 70% of the active excursion—only 61% of the functional excursion of our previously published data on normal subjects.[12] The mean postoperative functional excursion was 86°: this appeared less than that required to undertake a full portfolio of routine activities of daily living.

In previous studies,[12–14] we limited ourselves to these group analyses, and we did not further analyse

Table 2
Mean preoperative and postoperative, active and functional flexion, extension, and excursion of the affected knee during 11 functional tasks

	Preoperative (mean, SD)	Postoperative 18 to 24 months (mean, SD)	p value*
Active flexion	104.3° (13.7°)	96.9° (13.2°)	0.004
Active extension	5.7° (4.8°)	0.8° (2.6°)	0
Active excursion	98.6° (14.6°)	96.1° (13.7°)	0.353
Functional flexion	89.7° (17.2°)	86.0° (12.0°)	0.250
Functional extension	-1.7° (3.9°)	-0.1° (4.7°)	0.045
Functional excursion	91.4° (16.5°)	86.0° (12.5°)	0.077

* Independent *t*-test of differences in mean with equal variances not assumed between values of preoperative and postoperative 18 to 24 months (p=0.05)

the data because there was little change in the groups' performance. Because the mean values of the group changed only slightly, there was a tendency to assume that all members of the group would have also changed slightly and that postoperative performance would match preoperative performance for each individual. This is an unjustified assumption as the introduction of this paper has indicated. It has been suggested that patients with different levels of preoperative flexion may fare differently to one another, and this may be predictable.

The correlation between preoperative and postoperative excursions was also tested. As suggested by the literature, no statistically significant correlation was found (Pearson's correlation coefficient [r]=0.129; p=0.415). Likewise, preoperative and postoperative functional excursion were only weakly associated, with borderline statistical significance (r=0.301; p=0.053). Active and functional excursions were associated with each other preoperatively (r=0.592; p=0.000) and postoperatively (r=0.642; p=0.000). Nonetheless, r-squared data indicated that only 35% of the variation in preoperative functional excursion could be accounted for by preoperative active excursion and that only 41% of the variation in postoperative functional excursion could be explained by postoperative active excursion. An individual's postoperative functional excursion was thus not predicted by preoperative active or functional excursion and was only weakly associated with postoperative active excursion.

As postoperative excursion was not associated with preoperative excursion, patients with low preoperative excursion should gain excursion following surgery, whereas those with high preoperative excursion should lose excursion. Figure 1 shows the change in active excursion (from the preoperative test to postoperative test) plotted against the patients' preoperative active excursion. This shows the amount of active excursion gained or lost across the spread of subjects as a result of the surgery. There was a significant negative correlation between preoperative active excursion and postoperative change in active excursion (r= –0.699; p=0.000). Ultimately, patients who were most restricted preoperatively gained most postoperatively, with the reverse also being true. Linear regression analysis was used to determine the line of best fit across the data: the transition from gain in excursion to loss of excursion after operation occurred between 90° and 95° of preoperative active excursion.

The data of this study were divided into 2 groups: patients with ≤90° preoperative active excursion (n=13) and patients with ≥95° active excursion (n=29). For the lower excursion group, 85% gained excursion whereas only 15% lost active excursion as a result of surgery. For the higher excursion group, only 17% gained excursion whereas 83% lost active excursion. A similar analysis was applied to the functional excursion data. For the lower preoperative active excursion group, 62% gained and 38% lost functional excursion on operation. For the higher preoperative active excursion group, only 24% gained and 76% lost functional excursion.

The difference in performance between the 2 subgroups was then tested for statistical significance using independent t-tests. The difference within groups across time was tested using paired t-tests. The results for the active excursion and for the functional excursion are presented in Tables 3 and 4, respectively. For active excursion, there was a significant difference of 26.1° in the mean active excursion between the 2 groups preoperatively. Postoperatively, the difference was only 2.7° and not significant. The lower excursion group showed a significant increase in active excursion, whereas the higher excursion group showed a significant loss of active excursion. For functional excursion, there was a significant difference of 17.3° in the mean functional excursion between the 2 groups preoperatively. Postoperatively, the difference was

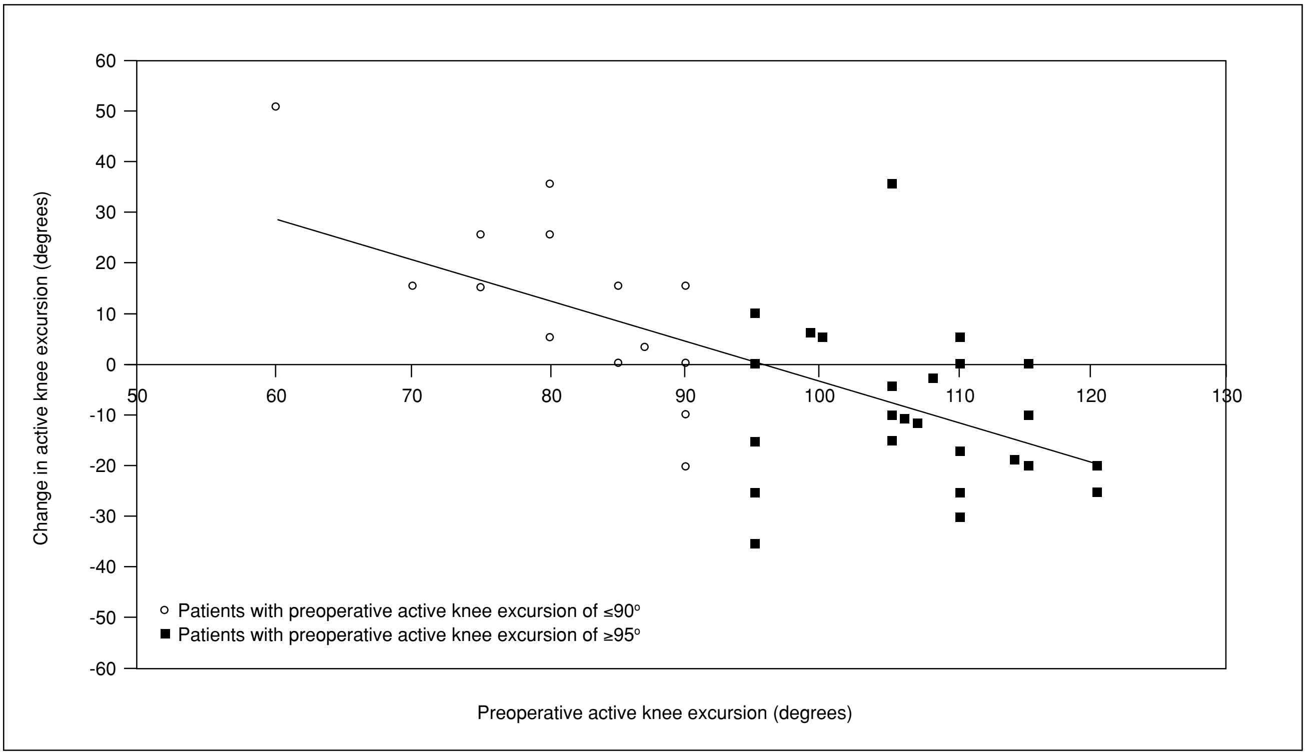

Figure 1 Correlation between preoperative active knee excursion and changes in active knee excursion (from preoperative to postoperative 18 to 24 months).

only 2.8° and again not significant. The lower excursion group showed a non-significant change in functional excursion, whereas the higher group showed a significant loss in functional excursion.

TKA appeared to produce a mean postoperative active knee excursion of 96°, with 95% of knees falling within the range of 69° to 123° (Table 2) regardless of the preoperative degree of active knee excursion. Likewise, TKA appeared to produce a mean postoperative functional knee excursion of 86°, with 95% of knees falling within the range of 61° to 110° (Table 2) regardless of the preoperative degree of functional knee excursion. Postoperative active and functional knee joint excursions remained substantially less than those seen in similar-aged healthy subjects and less than those required to perform many activities of daily living.[12] It could be argued that these deficits were of little importance to the patients when compared with the gain in performance due to the removal of pain and increase in general mobility. If this is correct, the active and functional excursions should be unrelated to quality of life.

The mean value of the 8 aspects of health recorded by the general health questionnaire is shown in Table 5. It shows the preoperative impact of osteoarthritis on patients. Physical functioning, role (physical), bodily pain, vitality, and social functioning were substantially lower preoperatively, whereas general health, role (emotional), and mental health were not. As a result, the preoperative physical components summary score (PCS) was lower whereas the mental component summary score (MCS) was not. This confirmed that the problems for these patients were principally physical. Postoperatively, bodily pain and, to a lesser extent, vitality improved and were close to normal levels for this age-group. Nonetheless, physical functioning and role (physical) remained depressed; therefore, the PCS though improved, remained below normal values. When the low and high preoperative active excursion groups were compared, little difference was observed in the scores for each group for any of the items assessed by questionnaire postoperatively.

Bivariate correlation analysis was undertaken using Pearson's correlation coefficient to explore the relationships between the active and functional excursions recorded postoperatively and the PCS and MCS of SF 36. This would help determine whether the

Table 3
Test for difference in mean active knee excursion between preoperative and postoperative assessments and between patients with preoperative active knee excursion of ≤90° and ≥95°

Preoperative active knee excursion	Mean active knee excursion		p value for paired *t* test
	Preoperative	Postoperative 18 to 24 months	
≤90°	81.3°	94.4°	0.014
≥95°	107.4°	97.1°	0
p value for independent *t*-test*	0	0.539	

* Differences in mean with equal variances not assumed

Table 4
Test for difference in mean functional knee excursion between preoperative and postoperative assessments and between patients with preoperative active knee excursion of ≤90° and ≥95°

Preoperative active knee excursion	Mean functional knee excursion		p value for paired *t* test
	Preoperative	Postoperative 18 to 24 months	
≤ 90°	80.0°	84.1°	0.376
≥ 95°	97.3°	86.9°	0.002
p value for independent *t*-test*	0.001	0.501	

* Differences in mean with equal variances not assumed

Table 5
Scores of SF 36 general health questionnaire comparing active knee excursion (preoperative and postoperative) of the patients with that of similar-aged healthy subjects

	Scores of SF 36 general health questionnaire*									
	PF	RP	BP	GH	VT	SF	RE	MH	PCS	MCS
Preoperative active knee excursion										
All patients	24	26	37	73	50	62	79	77	28	56
Patients with ≤90°	25	15	40	76	54	56	81	84	27	58
Patients with ≥95°	22	15	41	73	50	57	83	83	26	58
Healthy subjects	76	76	77	68	62	86	85	76	50	50
Postoperative active knee excursion										
All patients	48	53	63	75	56	83	100	84	37	60
Patients with ≤90°	42	48	62	78	54	83	100	85	35	60
Patients with ≥95°	51	55	63	74	57	83	100	84	37	59
Healthy subjects	76	76	77	68	62	86	85	76	50	50

* PF denotes physical function, RP role (physical), BP bodily pain, GH general health, VT vitality, SF social function, RE role (emotional), MH mental health, PCS physical component summary, and MCS mental component summary

spread in postoperative active and functional excursion values accounted for any of the variation in quality of life exhibited by the subjects. Postoperative active knee excursion did not correlate with PCS or MCS. Postoperative functional excursion was correlated to the PCS ($p=0.048$, $r=0.315$): lower postoperative functional knee excursion was associated with poorer physical quality of life.

DISCUSSION

The results of this study suggest that preoperative active excursion of the knee does not predict postoperative active or functional excursion of the knee or the patient's subsequent general health or quality of life. Postoperative function of patients was unrelated to their preoperative status. This confirms previous findings.[3] All postoperative results tend to be within a predictable range—a single range to which all the preoperative values migrate. There were no significant correlations between the low and high preoperative active flexion groups for either postoperative active excursion or postoperative function excursion or postoperative SF 36 scores. All patients appeared to have achieved a similar range of outcomes for active ROM, functional ability, and quality of life regardless of the severity of the restriction in range of joint movement preoperatively. It is important to note that these findings may not apply to all patients undergoing arthroplasty, because this study excluded severely disabled patients who were unable to mobilise in a substantial way preoperatively. Nonetheless, the present study group involved a broad range of preoperative patients and may be considered fairly representative of the typical knee arthroplasty candidate.

Patients with low preoperative excursion in the joint tend to gain excursion, whereas those with high preoperative excursion tend to lose. The majority of our patients with ≥95° preoperative active excursion lost excursion on surgery, whereas those with ≤90° gained. This information will help patients make informed decisions about treatment. For most patients, the outcome of surgery is likely to be a loss of active ROM and functional excursion in activities of daily living. Postoperative active excursion is likely to be less than that required for routine daily activities. Functional activity is likely to show significantly reduced knee excursion, and physical quality of life is likely to be less, compared with that of healthy subjects of similar age.

TKA is a highly successful procedure that substantially reduces pain and improves quality of life for many patients. Postoperative physical quality of life is nonetheless substantially reduced, and lower functional excursions are significantly associated with poorer physical quality of life. These observations lead one to consider whether changes can be made to the design of the implants, the surgical technique used, and the rehabilitation regimens implemented in order to improve postoperative functional excursion and produce better functional outcome and quality of life. It is not known whether further improvements in outcome can be achieved by a greater emphasis on the restoration of postoperative functional excursion.

This appears to be the first study to scientifically assess functional ROM using a portfolio of graded functional activities and to relate these data to the subject's quality of life and active ROM. Measures of active and passive ROM of the knee taken in a non–weight bearing situation on a couch are the main functional outcome measure for most trials in knee arthroplasty and for national and international knee arthroplasty registries and databases. In this small study of 50 subjects, preoperative active excursion had little predictive value for postoperative active excursion, functional ability, and quality of life. Further postoperative active excursion was only moderately associated with functional excursion and showed no association with physical quality of life. Functional excursion values have greater content validity. They show the usage of the joint during meaningful activities and are associated with physical quality of life. Although time and cost factors might prohibit the use of electrogoniometry methods and the SF 36 questionnaire in routine clinical practice, they provide significant additional information and more appropriate appraisal of outcome in a research setting than active range of motion alone.

CONCLUSION

The ultimate goal of TKA is to provide the best possible outcome for patients.[3] What is of relevance to the patient is not the active ROM in a non–weight bearing situation but the ability to use the replaced joint performing normal activities of daily living and hence to enjoy a high standard of physical quality of life. The outcome of TKA should thus be assessed using outcome measures that reflect these issues. Improvements are still required in restoring functional ability and quality of life for TKA patients. Although TKA provides great benefits, these benefits should not obscure the findings of this study. The majority of subjects gain little functional movement of the knee following surgery and continue to show reduced functional ability and physical quality of life 18 to 24 months after surgery, compared with healthy individuals of similar age.

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