J. Phys. Ther. Sci. 33: 672–675, 2021

The Journal of Physical Therapy Science

Original Article

Factors affecting early knee-flexion range of motion after total knee arthroplasty

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Abstract. [Purpose] To investigate the factors affecting the knee-flexion range of motion in the early period after total knee arthroplasty. [Participants and Methods] Ninety-nine patients who had undergone total knee arthroplasty at our hospital between 2016 and 2019 were allocated into two groups based on the presence of a 110° knee-flexion range of motion at 14 days post-surgery. From medical records, we extracted data for the participants' basic attributes and preoperative/postoperative physical function (knee-flexion range of motion, Timed Up & Go Test results, resting/walking pain according to a numerical rating scale, and knee-extension muscle strength). Postoperative physical function was measured 14 days post-surgery. [Results] Preoperative knee-flexion range of motion, preoperative femorotibial angle, postoperative knee-extensor strength, and postoperative Timed Up & Go Test value differed significantly as factors related to achieving a 110° knee-flexion range of motion. Through further statistical analyses, we selected the preoperative knee-flexion range of motion, preoperative femorotibial angle, preoperative Timed Up & Go Test result, and postoperative knee-extension strength as factors affecting the knee-flexion range of motion at 14 days post-surgery. [Conclusion] Preoperative knee-flexion range of motion, preoperative femorotibial angle, preoperative Timed Up & Go Test result, and postoperative knee-extension strength influence knee-flexion range of motion at 14 days after total knee arthroplasty, and our findings indicate the effectiveness of active physiotherapy interventions.
Key words: Total knee arthroplasty, Knee-flexion range of motion, Early rehabilitation

(This article was submitted Apr. 27, 2021, and was accepted Jun. 6, 2021)

INTRODUCTION

Osteoarthritis of the knee (knee OA), which is one of the leading causes of knee pain according to a recent large-cohort study, has been attracting considerable research attention. Among Japanese people aged >40 years old, the prevalence of knee OA is 42.6% in males and 62.4% in females, with the number of patients in Japan estimated to be 25.3 million[1)]. Patients with knee OA frequently present knee pain and knee instability as their main symptoms and experience impaired daily life[2)], and restrictions on social participation and leisure activities lead to a decline in their quality of life (QOL)[3)]. For knee OA, conservative treatment centered on patient education and exercise therapy, drug therapy is commonly selected[4)]; however, if knee OA progresses, total knee arthroplasty (TKA) is performed to overcome their knee-related disabilities[5)]. TKA typically improves physical function, pain, and Activities of Daily Living (ADL) substantially, and TKA is highly correlated with the degree of improvement shown by patients[6, 7)]. However, although TKA alleviates pain and enhances motor function, it leads to limited range of motion (ROM) of the knee joint, weakness of the quadriceps, and limited basic movement ability such as walking and climbing stairs in the early postoperative (post-) period[8)]. There are many Japanese lifestyles, and floor movements such as tatami mats and crouching are required. These movements are adverse because it is presumed that deeper

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knee flexion ROM and eccentric quadriceps contraction are required. Furthermore, for shortening the hospitalization period, it is essential to improve knee-flexion ROM to achieve ADL that assumes life on the floor.

Recently, knee-flexion ROM after surgery has been markedly improved by enhancing implant design and surgical techniques. However, pre-knee flexion ROM limitation has been reported to be the cause of post-knee flexion ROM limitation[9, 10)], the knee-flexion ROM obtained after TKA can show patient-to-patient variation. Therefore, examination of the factors affecting knee-flexion ROM in the early post-period is expected to help further improve the QOL of patients, and this, in turn, will contribute toward shortening the length of hospital stay and reducing medical expenses. Thus, we conducted this study to investigate the factors that affect knee-flexion ROM in the early post-period in patients after TKA at our hospital.

PARTICIPANTS AND METHODS

The study participants were 99 patients who were admitted to our hospital between May 2016 and June 2019 and underwent their first unilateral TKA after preoperative (pre-) physical therapy (Table 1).

We excluded patients who underwent surgery for fractures, patients with postoperative fractures, and patients who were unable to walk before surgery. The patients were classified into two groups based on a knee-flexion ROM of 110° being achieved at 14 days after the surgery. On the 14 days after surgery, patients with knee-flexion passive ROM (Knee ROM) of 110° or more were classified as an Achieved group, and patients with knee ROM of less than 110° were classified as an Unachieved group. The clinical evaluations were retrospectively collected from medical records. As basic information, we extracted age, body mass index (BMI), preoperative femorotibial angle (pre-FTA), operative method, implant type, surgical time, and bleeding time. For physical-function evaluation, we extracted resting pain and walking pain according to a numerical rating scale (NRS), knee ROM, knee-extensor strength in manual muscle testing (knee-extensor strength), one-leg standing time, and Timed Up & Go Test (TUG test) result; the data for physical-function evaluation were collected before and at 14 days after surgery. Pain intensity was scored according to the NRS, where “0” represents “no pain” and “10” means “maximal pain.” Knee-extensor strength was measured on participants while they were seated on a chair, and numerical grades (0–5) were assigned based on the patients’ ability to activate the knee extensors, move the knee through its available range, and hold against external force[11)]. To measure one-leg standing time, the patients were asked to stand on one leg for as long as possible without supportive tools, with their eyes open; for each patient, the time was measured until the stance foot shifted or the lifted foot was replaced on the floor, and two trials were conducted in each case[12)]. In the TUG test, the measurement was the time taken by a patient to rise from an armchair (seat height, 46 cm), walk 3 m, and turn and return to the sitting position in the same chair without physical assistance[13)]. This study was approved by the ethics review committee at Saitama Medical University Saitama Medical Center (Approval No. 2252). Statistical analysis was performed using SPSS Statistics Version 25 (IBM SPSS Statistics for Macintosh, Version 25.0, Released 2019; IBM Corp., Armonk, NY, USA). In comparing the two groups, the presence or absence of post-knee ROM of 110° was used as the explanatory variable and the clinical evaluations were used as the independent variables. Moreover, we conducted a multivariate logistic-regression analysis that included age, gender, preoperative TUG time (pre-TUG), and postoperative (post-) pain during walking. We used forward selection by likelihood-test ratio as the variable selection for the multivariate logistic-regression analysis. The significance level was set at $p<0.05$.

RESULTS

We found significant differences in preoperative (pre-) knee ROM, pre-FTA, postoperative (post-) knee-extensor strength, and post-TUG as factors related to the acquisition of knee-flexion ROM of 110° ($p<0.01$) (Table 2).

Pre-knee ROM, pre-FTA, pre-TUG, and post-knee-extensor strength were selected based on the results of the multivariate logistic-regression analysis. The odds ratio was 1.05 for pre-knee ROM, 0.91 for pre-FTA, 1.10 for pre-TUG, and 2.27 for post-knee-extensor strength (Table 3).

Table 1. Basic attributes of study participants (n=99)

	Achieved group (n=38)	Unachieved group (n=61)	p value
Age (years)	75.3 ± 7.7	74.7 ± 8.1	0.92
Gender (females, %)	28, 73.7%	51, 83.6%	0.23
Height (cm)	150.9 ± 8.2	150.9 ± 8.2	0.29
Weight (kg)	61.2 ± 8.2	61.6 ± 12.7	0.80
BMI (kg/m^2)	26.3 ± 4.8	26.9 ± 3.7	0.29

Continuous variables are presented as mean ± standard deviation (SD).
Achieved group: The patients with knee flexion ROM of 110° or more on the 14 days after the surgery.
Unachieved group: The patients with knee flexion ROM of less than 110° on the 14 days after the surgery.

Table 2. Comparison of clinical evaluations in Achieved and Unachieved groups (n=99)

	Achieved group (n=38)	Unachieved group (n=61)
Pre-FTA (°)	182.8 ± 8.0	185.7 ± 7.7*
Pre-knee ROM (°)	123.6 ± 16.4	111.9 ± 22.7**
Pre-knee-extensor strength (0-5)	5 (4−5)	5 (4−5)
Pre-one-leg standing time (s)	8.3 ± 14.1	8.0 ± 12.4
Pre-TUG (s)	14.0 ± 9.8	12.6 ± 7.1
Post-pain during walking (1-10)	2.6 ± 2.4	3.1 ± 2.6
Post-knee ROM (°)	115.8 ± 5.4	94.8 ± 11.5***
Post-knee-extensor strength (0-5)	4 (4−4)	4 (2−4)
Post-one-leg standing time (s)	7.3 ± 10.6	5.4 ± 11.3
Post-TUG (s)	13.8 ± 6.2	17.2 ± 10.9

Continuous variables are presented as mean ± standard deviation (SD).
Knee-extensor strength are presented as median (inter quartile range).
Achieved group: The patients with knee flexion ROM of 110° or more on the 14 days after the surgery.
Unachieved group: The patients with knee flexion ROM of less than 110° on the 14 days after the surgery.
Pre: Preoperative; Post: Postoperative; FTA: femorotibial angle; Knee ROM: knee flexion range of motion; TUG: Timed Up & Go Test.
*p<0.05, **p<0.01, ***p<0.001.

Table 3. Factors affecting knee-flexion ROM of 110° at 14 days post-TKA (multivariate logistic-regression analysis)

	B	SE	p value	Odds	95% CI	
					Min	Max
Pre-knee ROM†	0.044	0.017	0.011	1.05	1.01	1.08
Pre-FTA†	−0.099	0.043	0.023	0.91	0.83	0.99
Pre-TUG†	0.092	0.038	0.015	1.10	1.02	1.18
Post-knee-extensor strength†	0.819	0.321	0.011	2.27	1.21	4.26
Constant	8.29	7.80	0.29	3,967.78		

Likelihood-ratio test, p<0.01; Hosmer-Lemeshow test, p=0.49; percentage of accurate classification: 77.2%.
B: regression coefficient; SE: standard error; Pre: Preoperative; Post: Postoperative; FTA: femorotibial angle, Knee; ROM: knee-flexion range of motion; TUG: Timed Up & Go Test.
†Presence or absence of acquisition of knee-flexion ROM of 110° at 14 days after the surgery; N=0, Y=1.

DISCUSSION

The Japanese lifestyle frequently requires walking or sitting on tatami mats and engaging in crouching movements; thus, it is critical to obtain a knee-flexion ROM after TKA that is suitable for the Japanese lifestyle. Post-knee ROM is influenced by pre-knee ROM, and a study reported that in poor cases of pre-knee ROM, of ≤75°, substantial improvement is not recorded even at 1 year after surgery[14)]. Additionaly, it has been reported that increasing 10° in pre-flexion angle, the post-flexion would rise by almost 6.5°, while by reducing 10° of pre-femorotibial angle, the flexion would be increased by almost 2.1° postoperatively[15)]. Pre-knee ROM restriction and deformity are accompanied by atrophy and shortening of the soft tissue around the knee joint, and thus improvement in the early post-period is insufficient[9)]. Moreover, a reduction in the elasticity of the extension mechanism, mainly of the quadriceps, has been reported to represent a leading cause of restriction of post-knee ROM[10)]. Post-knee ROM is readily affected by the soft tissue around the knee joint before surgery, and even if the alignment is corrected by surgery, enhancing the properties of the soft tissue can be challenging; the soft tissue is considered to be affected before surgery. Therefore, from the results of this study, it is considered that physiotherapy intervention for improving pre-knee ROM is important for improving the post-knee ROM.

However, in this study, unlike previous studies, it was found that not only pre-knee flexion contracture but also post-knee extensor strength affects post-knee ROM as well. After TKA surgery, the quadriceps output decreases due to surgical invasion, neurogenic reflex suppression, and intra-articular swelling[8)]. Moreover, the fear of pain induction tends to cause defensive contraction of the quadriceps during knee flexion[16)]. In terms of knee ROM, TKA incises the quadriceps, and several patients thus experience difficulty in flexing the knee joint due to the hypertonicity of the quadriceps caused by the weakness of the muscle. Consequently, it is essential to control post-inflammation and muscle tone by positioning the quadriceps for post-invasion and intra-articular swelling. Therefore, we suggest that physiotherapy intervention for post-inflammation management and improvement of muscle output centering on the quadriceps could be related to the enhancement of post-knee

ROM. Thus, by expanding pre-knee ROM and improving post-knee extension strength, ADL such as on-floor movement and stair climbing may be acquired faster, leading to early discharge from home. However, the following limitations should be considered while interpreting the results of this study. First, the study had a small sample size as it involved only one facility. Second, the knee-extension muscle strength cannot be measured accurately using a device such as a hand dynamometer. Hence, further investigation is necessary.

In conclusion, pre-knee ROM, pre-FTA, pre-TUG, and post-knee-extensor strength were selected as factors affecting knee ROM at 14 days after TKA. Our results further suggest the usefulness of physiotherapy interventions such as improvement of pre-knee ROM, enhancement of post-knee-extensor strength, and suppression of defensive contraction.

Conflict of interest

The authors declare no conflict of interest.

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