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ORIGINAL ARTICLE

Recovery of knee range of motion after total knee arthroplasty in the first postoperative weeks: poor recovery can be detected early

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Abstract

Purpose The aim of this study was to analyze in detail how knee flexion and extension progress in the first 8 weeks after primary total knee arthroplasty (TKA). The secondary goal was to compare knee range of motion (ROM) recovery patterns between patients with normal and delayed ROM recovery 8 weeks after TKA.

Methods This prospective clinical trial included all patients who underwent a primary unilateral TKA between February and December 2016 with weekly ROM data documented by the treating outpatient physical therapists ($n = 137$). Goniometry was used to measure knee ROM preoperatively, postoperatively on day 1 and weekly until follow-up at the orthopedic clinic 8 weeks after surgery. ROM recovery patterns were compared between patients with sufficient ($\geq 90°$) or insufficient ($< 90°$) knee flexion 8 weeks after TKA.

Results Knee flexion recovered from a median of 80° in the first postoperative week to 110° 8 weeks after surgery and knee extension from a mean of −10.7° to −3.2°. Recovery was nonlinear, with greatest improvements in the first 4 weeks for knee flexion. In contrast to patients with sufficient knee flexion 8 weeks postoperatively, the insufficient group ($n = 8$, 5.8%) had poor knee flexion on the first postoperative day and from week 4 to week 8 almost no improvement or even worsening of knee flexion.

Conclusions Both knee flexion and extension recover in a nonlinear manner after TKA surgery. Poor postoperative knee function can be detected early, using ROM data from the first postoperative day up to the fourth week.

Keywords Total knee arthroplasty · Range of motion · Recovery patterns · Early postoperative

Introduction

Knowing the normal recovery curves of knee range of motion (ROM) after total knee arthroplasty (TKA) in the first postoperative weeks may allow early detection of patients whose recovery falls below what is expected. Early identification of these patients potentially allows enhanced interventions to be initiated by therapists or surgeons before it is too late.

Enhanced recovery programs for knee replacement surgery have safely reduced surgical impact and length of hospital stay [1, 2], but optimizing recovery after hospital discharge is more difficult [3–5]. Although there is no consensus on the optimal rehabilitation strategy for patients with a TKA, the goal is to prepare the patients to resume their activities of daily living (ADL), including work and sports participation. Rehabilitation after hospital discharge should therefore aim at reducing postoperative pain and swelling, regaining muscle strength and recovering knee ROM [6]. In case of insufficient knee ROM recovery, patients may have a stiff knee inhibiting TKA function for weeks or even several months after initial surgery. It can even result in permanent dysfunction, thereby limiting quality of life [7].

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Unfortunately, detailed information about early knee ROM recovery following primary TKA is scarce. ROM is known to increase after an arthroplasty, but the rate and extent have not yet been thoroughly studied. Almost all studies have measured knee ROM after TKA only at rather large intervals, e.g., 2 weeks, 1 month and 3 months [8–11]. Therefore, the primary aim of our study was to analyze in detail how knee flexion and extension progress in the first 8 weeks after primary TKA. Our secondary goal was to compare knee flexion and extension recovery patterns between patients with normal and delayed ROM recovery 8 weeks after TKA.

Materials and methods

Patients and surgical procedure

This prospective, single-center study (carried out at St. Anna hospital, Geldrop, the Netherlands) included all primary unilateral TKA procedures for which ROM data had been documented by the treating outpatient physical therapists. The regional research ethics review board approved the study (number: N16.071). All patients received a cemented total knee prosthesis (Vanguard®, Zimmer Biomet Inc. Warsaw, USA) between February and December 2016, implanted by one of five experienced TKA surgeons. A standard medial parapatellar approach was used in all cases. Surgical technique was not altered during the study period and included per-operative local infiltration analgesia (150 ml Naropin 0.2%), no tourniquet use and no patella button as a standard procedure. No wound drains were used, and each patient was given tranexamic acid (one dose immediately before incision and a second dose 6 h after surgery, 500 mg up to 1500 mg based on body weight).

First mobilization was scheduled < 6 h after the procedure, with weight bearing as tolerated. During hospital stay, supervised knee ROM and quadriceps muscle strengthening exercises were done twice a day. Patients were instructed to exercise several times a day and to continue exercising after discharge. All were referred to outpatient physical therapy. A protocol describing in detail the rehabilitation during the first 8 postoperative weeks was given to each physical therapist involved in this study. In addition, we reviewed a random sample of 54 physical therapy files from patients who underwent a TKA procedure during the study period, checking them for compliance with the prescribed rehabilitation protocol.

ROM measurements

Knee ROM was measured preoperatively by the orthopedic surgeon and postoperatively on day 1 by the physical therapist. All patients were scheduled for follow-up at the orthopedic clinic 8 weeks after surgery, where knee ROM was again measured by the orthopedic surgeon. At discharge, patients were given a letter for the treating physical therapist describing the rationale and protocol of the study, including a detailed description of the weekly ROM measurement procedure. Knee flexion and extension were measured using a long-arm goniometer, with the patient in supine position. The greater trochanter of the femur at the hip, the lateral femoral condyle at the knee and the lateral malleolus at the ankle were used as anatomic landmarks. Limited knee extension was noted as a negative value. This resulted in standardized ROM measurements by multiple observers, which is acceptable for comparison at a group level (ICC 0.88, 95% CI 0.77–0.94 for passive knee flexion in supine position) [12]. See Fig. 1a (flexion) and 1b (extension).

Knee ROM measurements were scheduled weekly until 8 weeks after surgery or earlier if rehabilitation goals had been achieved. To increase compliance with data collection, all physical therapists were contacted 1 week after the patients' discharge from hospital. Knee flexion was considered sufficient if ≥ 90° of flexion was achieved 8 weeks after surgery and insufficient if knee flexion was < 90° at this time point.

Demographic data of patients were collected, including age at time of surgery, body mass index (BMI), gender and American Society for Anesthesiologists (ASA) score.

Fig. 1 Measurement of **a** passive knee flexion, **b** active knee extension

Statistical analysis

Descriptive statistics were used to describe patient demographics and outcomes. To increase homogeneity, only patients who received a cruciate retaining prosthetic design were included. Patients were excluded if > 2 physiotherapy ROM data points were missing. If week 8 ROM data was missing, last observation carried forward was applied. Data were checked for distribution type, with normally distributed data presented as mean and standard deviation (SD) and nonparametric data as median and interquartile ranges (IQR). Statistical tests were chosen accordingly to compare data between groups. Weekly postoperative physiotherapy ROM data were tested for linearity. Subgroup analysis was based on the distinction between patients with sufficient (≥ 90° of knee flexion 8 weeks after surgery) and those with insufficient knee flexion.

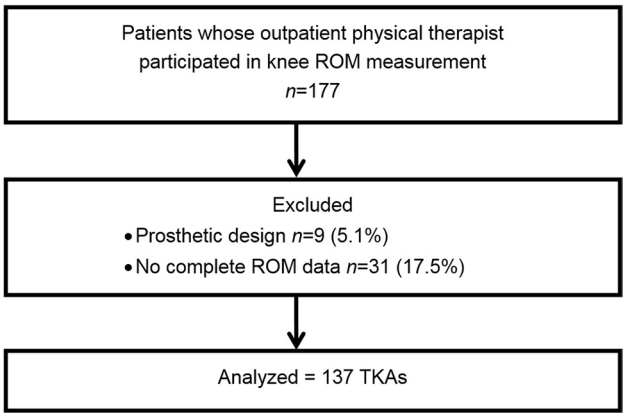

Fig. 2 Patient flow

A sensitivity analysis was carried out to compare the group whose ROM data had been documented by the outpatient physical therapist with the group for whom no outpatient physiotherapy data were available (control group). For this purpose, the 8-week ROM data obtained by the orthopedic surgeon were compared between these two groups, as were preoperative knee flexion, age and gender. An alpha of .05 was considered statistically significant for all statistical tests, and SPSS (version 19.0, Chicago, Il, USA) was used for all statistics.

Results

Weekly ROM data were analyzed for 137 TKAs. Of the 177 patients whose outpatient physical therapist measured the ROM of the knee postoperatively, 31 had incomplete ROM data (17.5%) and were excluded. Another 9 patients (5.1%) were excluded due to a different prosthetic design (posterior stabilized) being used. See Fig. 2 for the patient flow and Table 1 for patient demographics. None of the 54 randomly checked physical therapy files deviated from the prescribed rehabilitation protocol.

Flexion

The number of observations for flexion at each time point ranged from 95 to 137. Knee flexion recovered from a median of 80° in the first postoperative week to 110° 8 weeks after surgery (Fig. 3 and Table 2). Improvement in knee flexion was nonlinear, ranging from a mean rate of 19.6° a week (in the first postoperative week) to 1.4° a week (weeks 7–8), with greatest improvements in the first

Table 1 Patient demographics

Preoperative factors	
Male/female *n* (%)	56/81 (40.9/59.1)
Age mean (SD, min–max)	68.0 (8.8; 47.2–89.3)
ASA 1/2/3 *n* (%)	18/101/18 (13.1/73.7/13.1)
OA/RA *n* (%)	135/2 (98.5/1.5)
BMI mean (SD, min–max)	29.5 (5.0; 21.3–43.8)
Pain at rest mean (SD, min–max)	46.9 (27.7; 0–100)
Pain with activity mean (SD, min–max)	69.4 (23.3; 10–100)
OKS mean (SD, min–max)	26.4 (7.7; 7–43)
Fear of movement mean (SD, min–max)	40.4 (7.8; 24–61)
Surgical factors	
Patient-specific guides/intramedullar alignment *n* (%)	123/14 (89.8/10.2)
Surgery duration, mean, minutes (SD, min–max)	41.0 (9.8; 24–71)
Intraoperative blood loss, median, ml (IQR)	150.0 (0.0–237.5)
LOS in hours, mean (SD, min–max)	51.9 (16.8; 12.0–168.7)

BMI body mass index, *LOS* length of stay, *ASA* American Society for Anesthesiologists score, *OA* osteoarthritis, *RA* rheumatoid arthritis, *OKS* Oxford Knee Score 0–48, Fear of movement was measured using the TAMPA scale 17–68, *IQR* interquartile range, *SD* standard deviation

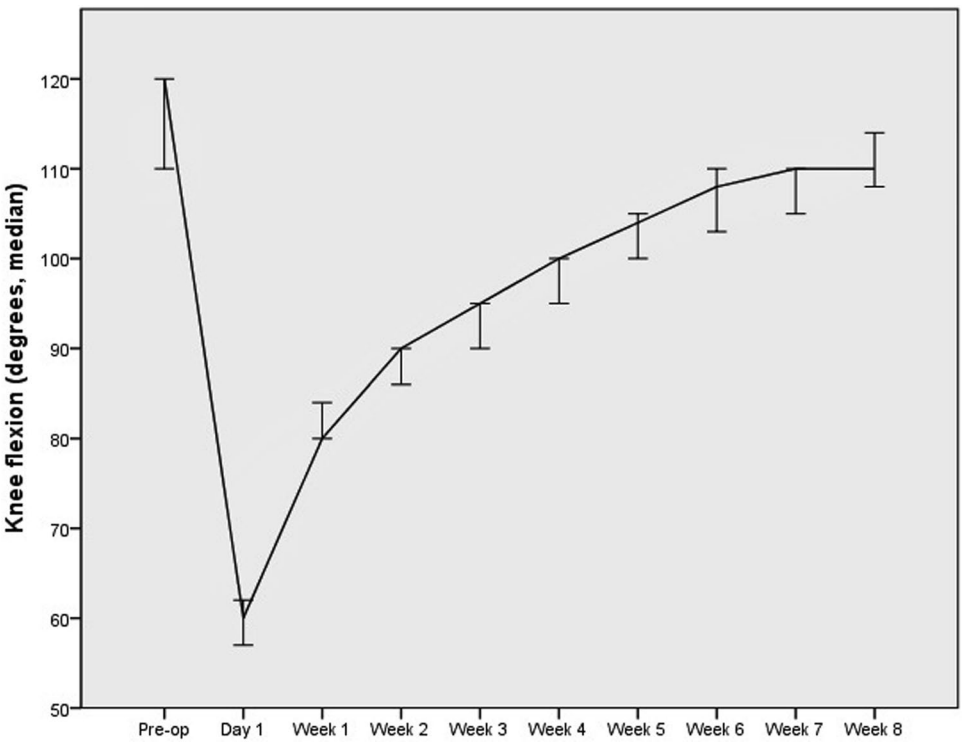

Fig. 3 Absolute knee flexion during the first 8 postoperative weeks (in degrees, median); error bars represent 95% confidence intervals

4 weeks (Fig. 4 and Table 3). In 8 cases (5.8%), knee flexion was < 90° 8 weeks after surgery. These cases were designated as the "insufficient ROM group," the remaining cases as the "sufficient ROM group." In the insufficient ROM group, the median knee flexion on the first postoperative day was much smaller than in the sufficient group (median 47.5° vs. 60.0°, respectively) and improvement in knee flexion decreased from week 4 onward, with worsening of knee flexion from week 7 to 8 (Fig. 5).

Extension

Knee extension recovered from a mean of − 10.7° after surgery to − 3.2° 8 weeks after surgery. This 8 week extension value was comparable with the mean preoperative value of − 3.5° (Fig. 6 and Table 2). Improvement in knee extension was nonlinear, ranging from a mean of 2.3° a week (in the first postoperative week) to 0.2° a week, with greatest improvements in the first 2 weeks (Fig. 6 and Table 4). In the sufficient ROM group, knee extension improved each week, while in the insufficient ROM group the change in knee extension fluctuated per week, worsening from weeks 2 to 3 and from weeks 7 to 8.

Complications in relation to stiffness of the knee

A total of 21 (15.3%) postoperative complications were observed, 18 of which were relevant (i.e., superficial postoperative wound infection, hematoma, swelling, persistent pain) in relation to the recovery of knee ROM. The 3 nonrelevant complications were one blister treated with necrotomy, one case of erysipelas and one case of an allergic reaction of the skin to medication. Of the relevant complications, 2 were in the insufficient and 16 in the sufficient ROM group, a difference which was not significant (Chi-square $P = 0.26$).

Of the 8 patients with insufficient knee flexion 8 weeks postoperatively, 4 were manipulated under anesthesia (MUA) (mean time to MUA 16.5 weeks, min–max 7–36 weeks), which improved their knee ROM by a mean of 36° (min–max 30°–40°) at final follow-up (mean 33 weeks after MUA). The 4 remaining patients either improved their ROM sufficiently with time ($n = 2$) or needed revision surgery due to instability ($n = 1$, 17 months postoperatively) or aseptic loosening ($n = 1$, 22 months postoperatively).

Sensitivity analysis

The sensitivity analysis regarding knee flexion for all patients who received a TKA during the study period ($n = 417$, all measured at the 8-week follow-up in the orthopedic office) demonstrated no difference between included patients ($n = 137$, median 110.0°) and control patients ($n = 280$, median 106.5°, $P = 0.577$). Nor was there any difference between the study group and control patients regarding age (study group mean age 68.0 years, control group 67.4 years, $P = 0.516$), gender (study group 40.9% male, control group 40.7% male, $P = 0.975$) and preoperative knee

Table 2 Knee ROM development per week (in degrees)

Absolute knee ROM values per week	Pre-op $n=95$	Day 1 $n=135$	Wk 1 $n=132$	Wk 2 $n=132$	Wk 3 $n=133$	Wk 4 $n=133$	Wk 5 $n=133$	Wk 6 $n=132$	Wk 7 $n=134$	Wk 8 $n=137$
Flexion (median/IQR)	120.0 (110.0–130.0)	60.0 (50.0–72.0)	80.0 (70.0–90.0)	90.0 (81.3–99.5)	95.0 (88.0–101.0)	100.0 (90.0–110.0)	104.0 (95.0–110.0)	108.0 (96.0–115.8)	110.0 (100.0–120.0)	110.0 (100.0–120.0)
Extension (mean/SD)	−3.5 (5.1)	−10.7 (5.0)	−8.5 (5.8)	−6.4 (6.2)	−5.6 (5.7)	−4.8 (5.3)	−4.6 (5.2)	−3.8 (4.8)	−3.4 (4.8)	−3.2 (5.0)

Pre-op preoperative, *Wk* week, *IQR* interquartile range, *SD* standard deviation

flexion (study group median 120.0°, control group median 120.0°, $P=0.858$).

Discussion

In our study, we found that the recovery of knee flexion and extension after TKA surgery was nonlinear, with greatest improvements in the first 4 weeks for knee flexion and in the first 2 weeks for knee extension. The pattern of knee flexion recovery in patients with insufficient knee flexion 8 weeks after TKA surgery was distinctively different from that in patients who achieved sufficient knee flexion at this time point. Besides having a more limited knee flexion on the first postoperative day, their knee flexion recovery was slower from week 1 onward, with even a decrease from week 7 to week 8.

We hypothesize that knee flexion and extension in the first 2–3 weeks after TKA surgery are mainly limited by postoperative pain, extensive swelling, collagen repair process and possibly patient anxiety. In the absence of these factors and of muscle tone, surgeons usually observe normal knee ROM values when testing at the end of the surgical procedure. In the first weeks after surgery, pain, swelling and anxiety usually improve quite dramatically, with a slower and more gradual improvement in the subsequent weeks. To achieve satisfactory knee function for most ADL, including going up and down stairs and getting up from a chair, 0°–110° of flexion is required [13, 14]. In our study, most patients achieved this knee ROM around 7– 8 weeks after surgery, which is similar to values reported by other authors [8, 10, 15]. These studies, however, did not measure ROM at a weekly interval for each patient and did not differentiate between normal and delayed ROM recovery in the first postoperative weeks. Surgeons and therapists can now compare the development of the knee ROM of their patients with our study data, allowing them to detect abnormal recovery of knee flexion after TKA with more certainty and accuracy, and possibly at an earlier stage.

To our knowledge, there have been three studies presenting detailed ROM recovery data. The study by Ebert et al. [16] used a methodology similar to ours (measuring knee ROM each week after TKA). The 108 patients they included showed an increase in mean active knee flexion of 90.4° (weeks 1–2) to 110.0° (weeks 6–7) [16], similar to our results. The study by Stratford et al. [15] used a variable-occasion repeated-measures study design, and their patients ($n=74$) achieved around 105° of flexion 8 weeks after surgery. A recent study by Mutsuzaki et al. [17], in which ROM was also measured intraoperatively and with a follow-up of 12 months, reported results similar to ours. However, their ROM measurements were less frequent in the

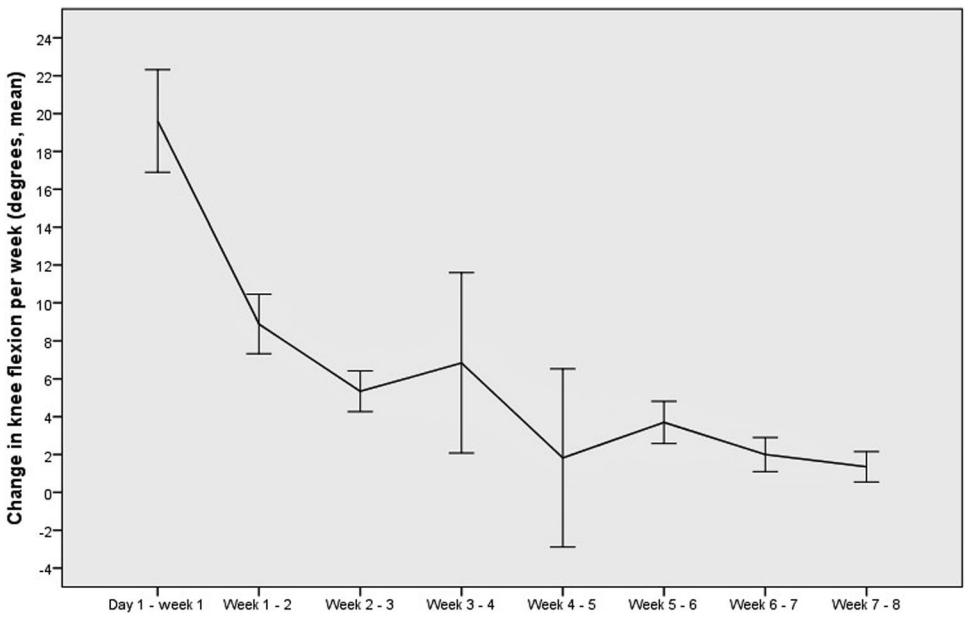

Fig. 4 Change in knee flexion per week, in degrees; error bars represent 95% confidence intervals

Table 3 Change in flexion ROM per week (in degrees)

Change per week Flexion (mean/SD)	Day 1–Wk 1 $n=131$	Wk 1–2 $n=128$	Wk 2–3 $n=129$	Wk 3–4 $n=129$	Wk 4–5 $n=130$	Wk 5–6 $n=129$	Wk 6–7 $n=129$	Wk 7–8 $n=134$
All	19.6 (15.7)	8.9 (9.0)	5.3 (6.2)	6.8 (27.3)	1.8 (27.2)	3.7 (6.4)	2.0 (5.2)	1.4 (4.7)
8 Wk sufficient	19.7 (15.8)	8.9 (8.8)	5.5 (6.1)	7.2 (28.2)	1.8 (28.0)	3.5 (6.1)	2.2 (4.4)	1.6 (4.4)
8 Wk insufficient	18.9 (15.8)	8.1 (12.3)	3.5 (7.5)	1.5 (5.7)	1.6 (1.8)	7.3 (9.8)	− 1.8 (11.9)	− 2.9 (7.1)

Wk week, *SD* standard deviation

first postoperative weeks and their study sample ($n=39$) was relatively small compared to ours [17].

Numerous factors, including patient, surgery and rehabilitation related issues, can cause poor postoperative recovery of knee ROM [18–20]. A stiff knee is a serious complication after TKA surgery, which may lead to hospital readmission and even MUA or revision surgery [21–23]. Several authors have reported MUA to be more successful if performed 3–6 weeks after surgery compared to beyond 6 weeks [24–26]. The results from our study may help to identify and predict poor ROM recovery at this very early (3–8 weeks) postoperative stage.

Besides applying MUA, surgeons often change the physiotherapy treatment in case of poor knee ROM recovery. This may involve either intensifying treatment (for patients who are insufficiently compliant with rehabilitation) or (temporarily) stopping or reducing exercising in case of too much knee reactivity, often with patients who are pushing too hard. There is, however, no detailed evidence available to decide what adjustments to postoperative rehabilitation should be made if poor knee ROM recovery is observed. Based on our study results, we recommend measuring knee flexion on the first postoperative day, to identify patients at risk of poor knee ROM recovery, and to schedule a follow-up assessment 4 weeks after surgery for these patients. If persistent poor ROM is observed at this follow-up, MUA might be indicated, since available evidence points toward MUA being more effective if performed early rather than late [25, 27–29].

A limitation of our study is that we did not fully control the nature (frequency, intensity, type of exercises) of the rehabilitation program, apart from providing each physical therapist with a protocol on how to rehabilitate our TKA patients. However, a random sample of physical therapy files from 54 patients showed no deviations from the prescribed rehabilitation protocol.

Another limitation is that we had multiple observers measure knee ROM, possibly compromising the accuracy. To standardize ROM measurements, we gave each participating physical therapist a written protocol on how to perform these measurements. Earlier research had shown that the interobserver reliability of knee ROM measurements

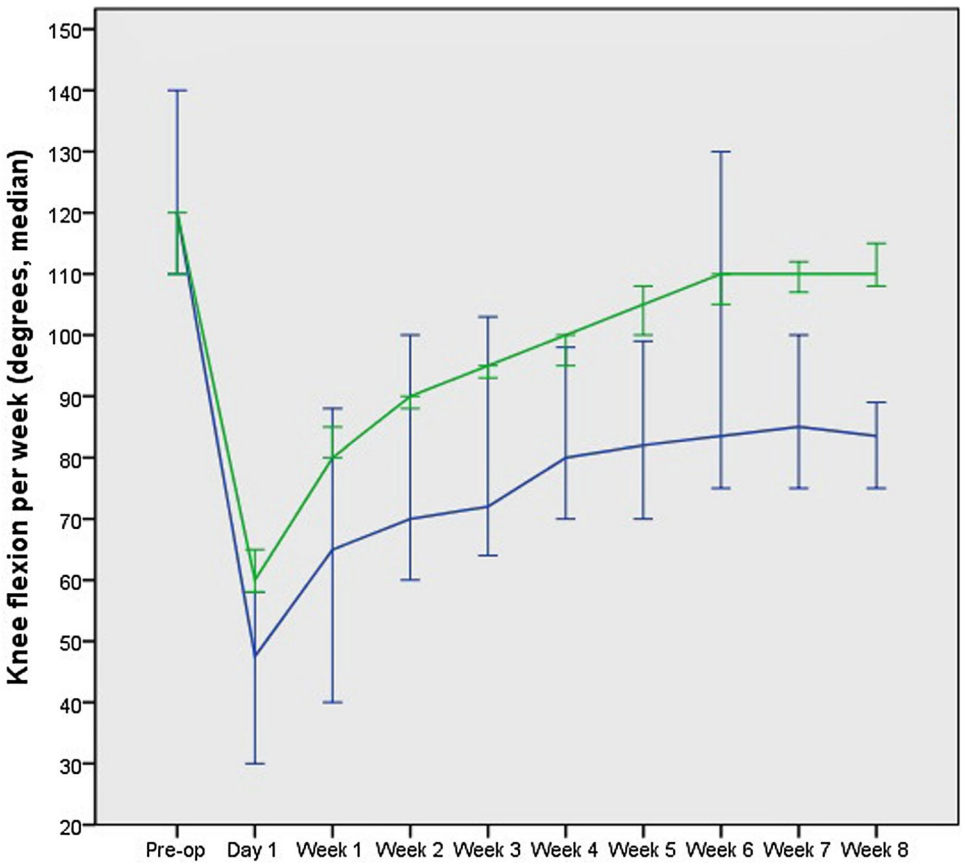

Fig. 5 Recovery of knee flexion per week, in degrees, for the sufficient ROM group (green line) and the insufficient ROM group (< 90° of flexion 8 weeks postoperatively, blue line); error bars represent 95% confidence intervals

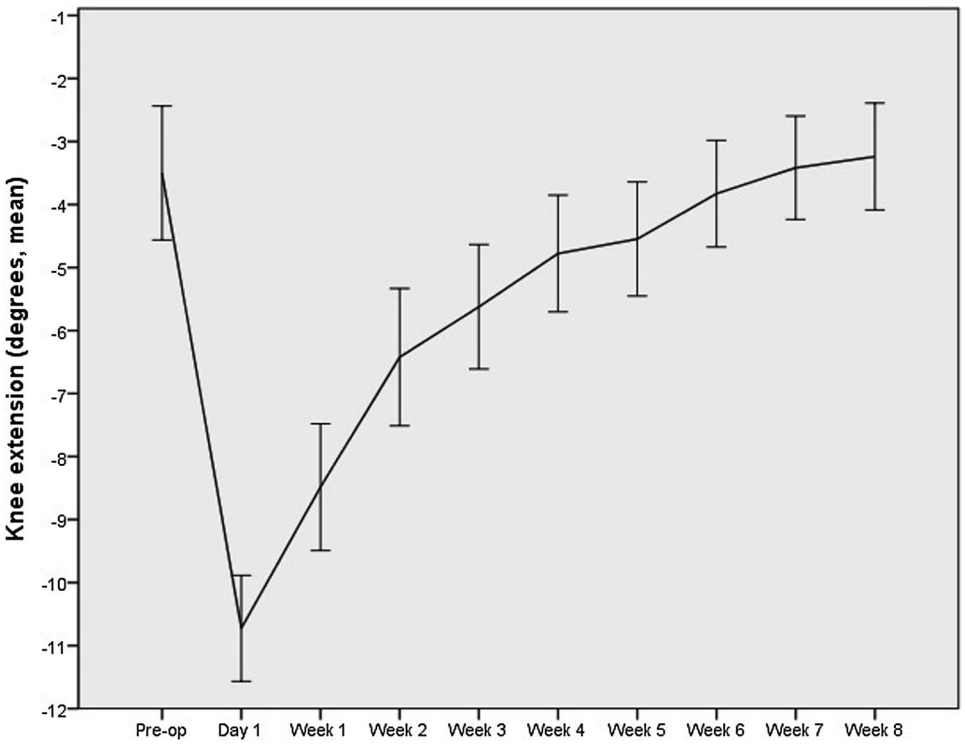

Fig. 6 Absolute knee extension during the first 8 postoperative weeks (in degrees, mean); error bars represent 95% confidence intervals

Table 4 Change in extension ROM per week (in degrees)

Change per week Extension (mean/SD)	Day 1–Wk 1 $n=130$	Wk 1–2 $n=125$	Wk 2–3 $n=125$	Wk 3–4 $n=126$	Wk 4–5 $n=127$	Wk 5–6 $n=125$	Wk 6–7 $n=125$	Wk 7–8 $n=131$
All	2.3 (6.5)	2.2 (4.8)	0.6 (5.7)	1.0 (2.9)	0.2 (2.3)	0.7 (2.3)	0.7 (2.1)	0.3 (2.2)
8 Wk sufficient	2.4 (6.6)	2.1 (3.5)	1.0 (2.7)	1.0 (2.9)	0.1 (2.2)	0.7 (2.3)	0.6 (2.1)	0.4 (1.9)
8 Wk insufficient	0.6 (4.7)	3.0 (14.4)	− 5.6 (20.1)	1.1 (2.0)	1.0 (3.0)	0.9 (1.7)	1.4 (2.5)	− 0.6 (5.3)

Wk week, *SD* standard deviation

using a goniometer resulted in acceptable outcomes at group level [12].

We only included TKA procedures for which the treating outpatient physical therapist agreed to do weekly ROM measurements, possibly introducing selection bias. However, our sensitivity analysis showed no difference in 8 week knee ROM values between patients treated by participating or non-participating physical therapists. In addition, there were no differences between the study group and the control group regarding age, gender or preoperative flexion.

Strengths of our study include its prospective design and the rather large cohort ($n=137$) we were able to include in comparison with similar studies [15–17].

Conclusion

Recovery of knee ROM in the first 8 weeks after total knee arthroplasty is nonlinear, with distinctively different patterns of ROM development between patients who achieve sufficient or insufficient knee flexion 8 weeks after surgery. Surgeons and therapists can use these patterns as an aid in detecting poor recovery of knee ROM after TKA, to adjust the postoperative rehabilitation or to treat patients with MUA at an earlier stage.

Compliance with ethical standards

Conflict of interest W van der Weegen is a paid consultant for Zimmer Biomet Inc.; all other authors have no conflict of interest to disclose.

Ethical statement All procedures were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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