



# Effects of two different continuous passive motion protocols on the functional activities of total knee arthroplasty inpatients

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**Objective:** The aim of this study was to compare the effects of two different continuous passive motion (CPM) application protocols (low- and high-angle) on the early phase functional activities of total knee arthroplasty inpatients.

**Methods:** The study included 170 patients who underwent primary TKA. While 84 of the TKA patients underwent low-angle CPM application, 86 of the patients underwent high-angle CPM application. The patients' functional activities were compared using the Iowa Level of Assistance Scale (ILAS), gait speeds using the Iowa Ambulation Velocity Scale (IAVS), knee scores using the Hospital for Special Surgery (HSS) Knee Score, and the duration of hospital stays with the Visual Analog Scale (VAS) preoperatively and on postoperative Day 2, Day 6, and at discharge.

**Results:** It was found that patients in the high-angle group had lower pain levels than did the patients in the low-angle group postsurgery ( $p<0.05$ ). Patients in the high-angle group achieved their functional activities more independently on postoperative Day 2, Day 6, and at discharge than did the patients in the low-angle group ( $p<0.05$ ). However, gait speed of patients in the former group was lower than that of the patients in the latter group ( $p<0.05$ ).

**Conclusion:** Although low-angle CPM application produced better results in terms of gait speed following TKA, the high-angle CPM application was superior in terms of independence levels of functional activities in the early postsurgery period. This result suggests that the appropriate use of rehabilitation methods such as CPM applications may guide clinicians to increase patients' level of independence.

**Keywords:** Total knee arthroplasty; continuous passive motion; functional activity; gait speed.

**Level of Evidence:** Level III Therapeutic Study

Total Knee Arthroplasty (TKA), an intervention performed to reduce pain in severe gonarthrosis and to increase range of motion (ROM), is one of the most frequently performed orthopedic surgical procedures. The

success of the surgical procedure is related not only to the increase in ROM and muscle strength but also to the increase in the patient's level of functional independence in the early postoperative period.<sup>[1]</sup> Reduced function-

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ality in the early postoperative period after TKA leads to increases in major complications such as pulmonary embolism, urinary incontinence, deep vein thrombosis, and bedsores. Therefore, patients should be seated on the edge of the bed and mobilized as soon as possible in the early postoperative period.<sup>[2]</sup>

Healthcare and evaluation protocols established in the early postoperative period after TKA are used to monitor the patient's functionality. Among them are movements such as sitting down, standing up, gait, and gait speed, all of which are important parameters of functional independence and discharge criteria.<sup>[3]</sup> For clinicians, it is important to evaluate these functional activities in the early postoperative period and to plan the treatment program during the treatment process. Determination of such changes in the functional levels of patients facilitates the proper and effective use of hospital resources.<sup>[3-5]</sup>

There are several physiotherapy methods to accelerate the healing process of patients in the early postoperative period after TKA. One of these methods is the widely-used continuous passive motion (CPM) implementation. The effectiveness of CPM implementations after TKA has been investigated through several studies and various protocols.<sup>[6]</sup> Although there are studies investigating the effects of the duration and postoperative application times of CPM implementations on normal knee joint motion, the length and costs of hospital stay, and complication rates,<sup>[1,7-9]</sup> there are no studies investigating the effects of CPM implementation on functional activity levels during the early postoperative period in a hospital setting.

In this study, the effects of low- and high-angle CPM protocols on functional activity levels of patients with TKA during the early postoperative period in a hospital setting were investigated.

## Patients and methods

The study was comprised of 170 patients (12 males, 158 females; mean age:  $67.1 \pm 7.9$  years; range: 44–87 years) who were diagnosed with bilateral osteoarthritis and underwent bilateral primary TKA performed by the same surgeon using the paramedian approach. The patients underwent successive bilateral TKA performed by the same surgeon during a single surgery and anesthesia session. All the patients had the same type of cemented prosthesis (NexGen, Zimmer Inc., Warsaw, IN, USA), in which the posterior cruciate ligament (PCL) structure is protected. Of the patients, those who had diseases of the heart, lung, kidney, gastrointestinal system or endocrine system, limited ROM due to neurological causes,

postoperative signs of infection in the knee, did not tolerate CPM implementations, developed significant complications (e.g., pulmonary embolism, heart attack, or wound healing problems) during hospitalization, and/or were not able to perform functional activities (e.g., rising from a chair, walking, ascending and descending stairs) were excluded from the study.

After TKA, patients underwent low-angle (4 males, 80 females; mean age:  $66.4 \pm 7.2$  years; range: 50–81 years) and high-angle (5 males, 81 females; mean age:  $67.7 \pm 8.5$  years; range: 44–87 years) CPM protocols. CPM was implemented without interruption at a speed ranging between  $1.5^\circ/\text{sec}$  and  $3.5^\circ/\text{sec}$ . The low-angle CPM implementation was initiated on postoperative Day 1 at  $30\text{--}40^\circ$ , and CPM angle was increased by  $10^\circ$  a day. CPM was discontinued upon reaching  $110^\circ$ . In the high-angle CPM implementation, the aim was to attain  $90^\circ$ -knee flexion on postoperative Day 3. Therefore, depending on the patient's tolerance level, CPM was implemented by setting the CPM device to  $60\text{--}70^\circ$  on the postoperative Day 1,  $70\text{--}80^\circ$  on Day 2, and  $80\text{--}90^\circ$  on Day 3. Following CPM application, a  $110^\circ$  knee flexion degree of motion was achieved in all patients. The patients underwent 1-hour CPM application twice a day during the treatment period. All patients received the standard physiotherapy program given by the same physiotherapist, which was started on postoperative Day 1. The program included respiratory and isometric-isotonic exercises, CPM application, active-assisted ROM exercises, walking, and transfer training.<sup>[10]</sup> All patients started walking on postoperative Day 1, first using a walker and then forearm crutches. Patients were asked to shift their body weight to their extremities to the extent they could tolerate. Of the patients, those who were able to achieve active knee extension to reach  $110^\circ$  in CPM application, to move from the supine position to the sitting position with mild or moderate assistance, to rise from the sitting position and walk, to ascend and descend stairs, and whose active knee flexion angles were between  $65\text{--}70^\circ$  were discharged.

Functional movements and gait speeds were assessed with the Iowa Level of Assistance Scale (ILAS) and Iowa Ambulation Velocity Scale (IAVS), respectively, presurgery, on postoperative Day 2 and Day 6, and at discharge (Tables 1, 2).<sup>[4]</sup> For the assessment of functional capacity, levels of moving from the supine position to the sitting position, rising from a sitting position, walking for 15 steps (4.57 m), and ascending and descending stairs for 3 steps were investigated (Table 1). With the gait speed test, the patients' gait speeds over 13.4 m (44 steps) were compared (Table 2).

**Table 1.** IOWA Level of Assistance Scale (ILAS).

Grade of IOWA Level of Assistance Scale	Score
Independent	6
Standby assistance	5
Minimal assistance	4
Moderate assistance	3
Maximal assistance	2
Failed maximal assistance	1
Not tested	0

In addition, patients' knee functions were assessed using the Hospital for Special Surgery (HSS) Knee Score, pain levels at rest and activity were assessed using the Visual Analog Scale (VAS), and hospital length of stay (in days) was additionally assessed (Table 4).

For statistical analysis of the data, the repeated measures analysis of variance (ANOVA) was used to determine the differences between the 2 groups. The data were analyzed using SPSS 22.0 for Windows (SPSS Inc., Chicago IL, USA). P values of <0.05 were considered statistically significant.

## Results

Descriptive characteristics of patients in the low- and high-angle CPM groups were similar ( $p > 0.05$ , Table 3). The mean length of hospital stay was greater in the low-angle CPM group ( $p < 0.05$ , Table 3).

**Table 2.** IOWA Ambulation Velocity Scale (IAVS).

Time of IOWA Ambulation Velocity Scale (seconds)	Score
$\leq 20$	0
21–30	1
31–40	2
41–50	3
51–60	4
61–70	5
$> 70$	6

While no differences were found between the 2 groups in terms of HSS scores and knee flexion degrees determined preoperatively and at discharge ( $p > 0.05$ , Table 4), pain levels at rest and activity determined with VAS at discharge were higher in the low-angle group ( $p < 0.05$ , Table 4).

Comparison of the patients in the low- and high-angle CPM groups conducted with ILAS on postoperative Day 2 in terms of their functional activities (moving from the supine position to the sitting position, rising from the sitting position, walking 15 steps [4.57 m], and ascending and descending stairs) revealed that patients in the high-angle group were more independent than patients in the low-angle group ( $p < 0.05$ , Table 5). The measurements conducted on postoperative Day 6 and at discharge revealed that patients in the high-angle group performed all the functional activities more indepen-

**Table 3.** Patients' descriptive characteristics and length of hospital stay.

	Low-angle continuous passive motion	High-angle continuous passive motion	p
Age (years)	66.4 $\pm$ 7.2 (50–81)	67.7 $\pm$ 8.5 (44–87)	0.315
Height (cm)	157.8 $\pm$ 7.6 (142–179)	158.0 $\pm$ 7.1 (143–180)	0.835
Weight (kg)	77.2 $\pm$ 12.0 (50–117)	78.4 $\pm$ 11.4 (57–113)	0.683
Length of hospital stay (days)	10.2 $\pm$ 3.5 (6–19)	7.6 $\pm$ 2.1 (6–16)	0.000*

\* $p < 0.05$ .

**Table 4.** Comparison of preoperative pain levels at rest and activity assessed with Visual Analog Scale, Hospital for Special Surgery Knee Score, and knee flexion angles with pain levels determined at discharge.

	Low-angle Continuous passive motion		High-angle Continuous passive motion		p <sup>1</sup>	p <sup>2</sup>
	Preoperative	Discharge	Preoperative	Discharge		
HSS Knee Score	59.8 $\pm$ 11.3	62.0 $\pm$ 8.5	58.7 $\pm$ 9.1	60.0 $\pm$ 7.7	0.483	0.106
Knee flexion degree (°)	101.1 $\pm$ 18.0	71.5 $\pm$ 13.5	104.2 $\pm$ 16.1	72.3 $\pm$ 16.0	0.245	0.745
Pain (Visual Analog Scale score)						
At rest	4.0 $\pm$ 2.5	3.0 $\pm$ 1.7	4.1 $\pm$ 2.3	2.3 $\pm$ 2.1	0.645	0.013*
During activity	6.6 $\pm$ 1.9	3.7 $\pm$ 1.9	6.4 $\pm$ 2.1	2.7 $\pm$ 2.0	0.629	0.001*

p<sup>1</sup>: Comparison of preoperative scores obtained by from patients in the low- and high-angle CPM groups; p<sup>2</sup>: Comparison of scores patients in the low- and high-angle CPM groups obtained at discharge; \* $p < 0.05$ .

**Table 5.** Comparison of scores patients obtained from ILAS and IAVS preoperatively, on postoperative Day 2 and Day 6, and at discharge.

	Low-angle CPM						High-angle CPM						F	p		
	Preoperative		Day 2		Day 6		Preoperative		Day 2		Day 6				Discharge	%
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD					
ILAS																
Supine-to-sit	4.6±1.4	2.6±0.5	3.5±0.6	4.1±0.9	12.46	4.8±1.4	2.7±0.6	3.7±0.7	4.8±1.0	2.07	10.62	0.001*				
Sit-to-stand	4.7±1.5	2.5±0.5	3.4±0.6	4.0±0.9	18.45	4.6±1.4	2.8±0.6	3.6±0.7	4.7±1.0	7.55	6.460	0.000*				
Ambulate 15 feet	4.2±1.6	2.5±0.5	3.3±0.6	4.0±1.0	28.41	4.2±1.5	2.7±0.6	3.6±0.7	4.7±1.0	13.35	5.125	0.000*				
Ascend and descend 3 stairs	3.4±0.9	2.6±0.5	3.0±0.6	3.0±0.6	53.73	2.7±1.1		3.0±0.5	3.5±0.8	41.58	4.222	0.000*				
IAVS																
Walking speed (13.4 m)	4.1±1.9	5.0±1.1	4.3±1.0	3.7±1.0	-39.32	4.0±1.7	5.7±0.6	5.0±0.6	4.2±1.1	-23.96	5.970	0.000*				

ILAS: Iowa Level of Assistance Scale; IAVS: Iowa Ambulation Velocity Scale; \*p&lt;0.05; CPM: Continuous passive motion.

dently ( $p<0.05$ , Table 5). However, patients in the low-angle group were determined to walk faster during the measurements conducted on postoperative Day 2 and Day 6 and at discharge ( $p<0.05$ , Table 5).

Regarding postoperative complications, 2 patients in the high-angle group and 1 patient in the low-angle group developed hematoma in the knee.

## Discussion

After TKA application, the acceleration of patients' mobilization and the improvement of their activities of daily living (ADL) play an important role in reducing complications likely to occur when patients are in bed for an extended period.<sup>[11,12]</sup> Moving from the supine position to the sitting position, rising from the sitting position, walking, and ascending and descending stairs are important ADL and are among the criteria taken into consideration when patients with TKA are discharged from the hospital. The Iowa scale used for the assessment of the functional movements in the early postoperative stage in patients with TKA is an easily applicable scale whose validity and reliability have been proven. Using this and similar scales for the assessment of functional levels of patients enables hospitals to use rehabilitation methods and their resources more efficiently.<sup>[4,13]</sup> Therefore, this scale was used in this study

While there is still substantial debate surrounding the short-term efficacy of CPM after TKA, it is still widely used in clinics by physiotherapists. In the literature, although there are articles indicating that CPM accelerates wound healing and reduces risk factors for deep vein thrombosis, its effects on knee ROM and other functional parameters remain in question.<sup>[7,8,14]</sup> In several studies conducted on knee ROM, an important parameter among the discharge criteria for patients with TKA, patients have been reported to have knee ROM between 61–80° in the early postoperative period (7–10 days post-surgery).<sup>[8]</sup> In several studies investigating the effects of CPM application on the recovery of knee ROM in the early postoperative period, while Bennet et al.<sup>[15]</sup> determined that high-angle CPM application was more effective than low-angle CPM application, other researchers reported that high-angle CPM application was not superior to low-angle CPM application.<sup>[7,16]</sup> In the present study, it was determined that neither low- nor high-angle CPM application affected the recovery of knee ROM. Indeed, normal knee ROM (72°) was achieved, which was consistent with the findings in the literature.

The length of hospital stay plays an important role in reducing arthroplasty-related complications and hospital costs. According to the Uniform Data System for Medi-



cal Rehabilitation (UDSM) database, the mean length of stay in hospitals is 8.8 days for TKA patients.<sup>[17,18]</sup> In the literature, there is a large body of research investigating the effects of CPM application on the length of stay in hospitals.<sup>[8,11,14,15]</sup> Although these studies reported that CPM application shortened the length of stay in hospitals by 2–6 days, in the literature, there is no consensus on this issue.<sup>[19,20]</sup> CPM protocols combined with standard physiotherapy programs and implemented at various durations have been reported to have no effect on the length of stay in hospitals (mean: 8 days).<sup>[8,21]</sup> In this present study, the mean hospital length of stay was 10.2 days in the low-angle CPM group and 7.6 days in the high-angle group. This result suggests that when the length of stay in hospitals is taken into account, high-angle CPM application can reduce complications such as infection and length of stay in hospitals, thus reducing costs of treatment.

Preoperative knee scores of TKA patients may provide clues for levels of postoperative functions.<sup>[13]</sup> In the present study, no significant differences were determined between the preoperative and postoperative HSS knee scores of the patients in the low- and high-angle CPM groups. This result appears to support the results of other studies in the literature investigating the effects of CPM application on knee functions in the early postoperative period.<sup>[1,7,14,22]</sup>

Functional activities such as moving from the supine position to the sitting position, rising from the sitting position, and gait speed are important in terms of the independence of patients.<sup>[3]</sup> In the literature, there is a gap related to the effects of different CPM applications on functional activities in the early postoperative period following TKA. Studies conducted on this issue using different surveys focused on the effects of standard physiotherapy applied at different durations on functionality in the early postoperative period. Lenssen et al.<sup>[23]</sup> conducted a study using the WOMAC questionnaire and indicated that there were no differences between the effects of standard physiotherapy and those of CPM implementations applied together with standard physiotherapy on the functional activities of patients in the early postoperative period. Beaupre et al.<sup>[7]</sup> determined similar results. Bennett et al.<sup>[15]</sup> demonstrated that CPM protocols applied at different ranges had no effects on Knee Society Scores (KSS). On the other hand, Akarcalı et al.<sup>[24]</sup> found that TKA patients who received accelerated CPM therapy and active physiotherapy gained earlier independence in straight leg lifting, walking, and ascending and descending stairs. The present study, conducted differently from the aforementioned studies, compared functional activity parameters in the early postoperative

period and found that patients in the high-angle CPM group experienced better results than patients in the low-angle CPM group in terms of functional activity levels in the early postoperative period. This result is of importance, as it revealed that patients in the high-angle CPM group met the discharge criteria in terms of functional activities earlier. In the present study, patients who underwent high-angle CPM therapy performed functional activities more independently and easily on the postoperative Day 2 and Day 6, and at discharge, which was probably resultant from their greater knee ROM.

Limitations in functional parameters of walking observed in the preoperative period in patients with TKA remain in the postoperative period.<sup>[25]</sup> Muscle strength and knee ROM decrease following TKA, leading to a decrease in gait speed. Patients' step length shortens and double support period prolongs, which leads to deterioration in gait pattern compared to healthy subjects.<sup>[25–27]</sup> Consequently, assessment of walking functions of TKA patients is vital in determining their level of independence in performing ADL. In the literature, there is a gap related to the effects of different CPM applications on gait patterns after TKA. Bruun-Olsen et al.<sup>[16]</sup> applied the Timed Up and Go Test (TUG) in order to compare the effects of active exercises and CPM application on walking ability and determined that there was no difference between the results they obtained at the postoperative first week and the third month assessments. In this present study, the effects of low- and high-angle CPM applications on gait speed were compared, and patients in the low-angle CPM group were found to achieve better gait speed scores, which was considered to result from their longer length of their stay in the hospital and longer rehabilitation program.

At the end of the CPM protocols applied at different ranges, it was determined that high-angle CPM application enabled the patients to regain functional activities earlier after TKA and thus shortened the length of stay in hospitals and reduced costs. On the other hand, low-angle CPM applications were found to have more positive effects on gait pattern.

The use of rehabilitation methods such as CPM within the framework of an appropriate protocol, which plays an important role in patients' regaining their functionality following TKA, may guide clinicians through the planning and implementation process. It was concluded that through these implementations, the effects of physiotherapy and rehabilitation programs provided for patients with TKA are maximized, while the costs are minimized.

**Conflicts of Interest:** No conflicts declared.

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