

# Effects of Rehabilitation Training on Range of Motion after Total Knee Arthroplasty

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**Abstract:** Total knee arthroplasty (TKA) serves as an effective intervention for end-stage knee osteoarthritis and other related disorders. Postoperative recovery of knee range of motion (ROM) directly determines patients' daily functional performance and quality of life. By reviewing domestic and international recent literature, this paper summarizes functional requirements and influencing factors of postoperative ROM, early-stage rehabilitation training, continuous passive motion, muscle-strength and proprioception training, pain and swelling management, multi-modal rehabilitation strategies, and synergistic application of Mongolian traditional therapies. Available evidence demonstrates that systematic rehabilitation training following the principles of early intervention, gradual progression, active-exercise priority and individualization can significantly improve postoperative knee flexion-extension ROM, and reduce the incidence of joint stiffness and adhesion. Multi-modal rehabilitation guided by enhanced recovery after surgery (ERAS) as well as integrated Mongolian-Western medicine rehabilitation pathways exhibit promising clinical prospects.

**Keywords:** Total knee arthroplasty; Rehabilitation training; Range of motion; Functional exercise; Review

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## 1. Introduction

Total knee arthroplasty is an effective treatment modality for end-stage knee osteoarthritis, rheumatoid arthritis and other joint diseases, which can substantially relieve pain, correct deformity and reconstruct joint function, with long-term clinical excellent rate exceeding 90% <sup>[1]</sup>. Accelerated population aging in China has contributed to rising prevalence of knee osteoarthritis. According to the *Guidelines for the Diagnosis and Treatment of Osteoarthritis (2018 Edition)*, the prevalence of symptomatic knee osteoarthritis reaches approximately 8.1% in China, forming a large population of end-stage patients accompanied by annually increasing TKA surgical volume, and other joint diseases, which can substantially relieve pain, correct deformity, and reconstruct joint function, with a long-term clinical success <sup>[2]</sup>.

Nevertheless, surgical success does not equal complete functional recovery. Satisfactory restoration of postoperative knee ROM, one of the core outcome indicators evaluating TKA efficacy, is decisive for patients' capacity to conduct daily activities including walking, stair ascending-descending, and sit-to-stand

transfers. Without systematic postoperative rehabilitation training, peri-articular soft tissues are prone to contracture and adhesion. Some patients suffer from limited flexion-extension; severe cases may develop fibrous joint adhesion that requires manipulation under anesthesia or even re-operation, thereby compromising surgical outcomes. Accordingly, it carries important clinical implications to systematically summarize the impacts and optimization strategies of rehabilitation training on ROM after TKA <sup>[3]</sup>.

## **2. Functional significance and influencing factors of postoperative knee ROM**

### **2.1. Functional requirements for range of motion**

Normal knee joint flexion can achieve more than 135°, while full extension reaches 0°. Biomechanical studies reveal that level-ground walking demands roughly 65–70° knee flexion; stair climbing requires approximately 83°; stair descending needs 90–100°; sit-to-stand transfer from a chair consumes 95–110°; movements such as squatting and squat-to-defecate require flexion greater than 110° <sup>[4]</sup>. It is generally acknowledged that postoperative knee flexion  $\geq 110^\circ$  can meet most demands of activities of daily living. Meanwhile, complete knee extension without residual flexion contracture is a prerequisite for normal gait. Hence, rehabilitation training should address both flexion and extension dimensions.

### **2.2. Major factors affecting postoperative ROM recovery**

Postoperative ROM restoration is affected by multifactorial variables.

#### **(1) Preoperative factors**

Baseline ROM, quadriceps strength, deformity severity, and comorbidities are powerful predictors of postoperative range-of-motion outcomes.

#### **(2) Intra-operative factors**

Prosthesis selection and placement, soft-tissue balancing, matching of flexion-extension gaps.

#### **(3) Postoperative factors**

Pain, swelling, intra-articular hematoma organization, adhesion formation, and patient rehabilitation compliance. Among these factors, scientific formulation and proper implementation of rehabilitation training constitute the most clinically modifiable component, which is the main focus of this review <sup>[5]</sup>.

## **3. Effects of early-stage rehabilitation training on joint range of motion**

### **3.1. Timing and contents of early rehabilitation**

The concept of enhanced recovery after surgery advocates initiation of functional exercise at the earliest postoperative phase. The *Chinese Expert Consensus on Peri-operative Management for Enhanced Recovery after Hip and Knee Arthroplasty* recommends that ankle-pump exercise and isometric quadriceps contraction be commenced immediately after anesthesia emergence, and out-of-bed mobilization under walker protection within 24 hours post-surgery <sup>[6]</sup>. Early exercise facilitates venous and lymphatic return, mitigates swelling, prevents disuse atrophy of quadriceps and capsular contracture, and lays groundwork for subsequent range-of-motion training <sup>[7]</sup>. Research conducted by Bade et al. demonstrated that patients receiving high-intensity early rehabilitation obtained superior ROM and functional scores at 6-month follow-up compared with the conventional rehabilitation group <sup>[8]</sup>. Training during postoperative day 0–3 mainly consists of bed-based interventions: ankle-pump movement, isometric contraction of quadriceps and

hamstrings, straight-leg raise, as well as walker-assisted standing and partial-weight-bearing ambulation.

### **3.2. Continuous passive motion (CPM)**

Continuous passive motion was first proposed by Salter in the 1970s <sup>[9]</sup>. Initially applied to experimental research on articular-cartilage repair, its theoretical basis lies in that continuous, pain-free and controllable passive movement can promote cartilage nutritional metabolism, inhibit adhesion formation and alleviate pain and swelling <sup>[10]</sup>. In clinical practice, CPM is usually initiated 24–48 hours post-operatively, with an initial motion arc set at 0–45°, increasing 5–10° daily, 30–60 minutes per session. A randomized controlled trial by Bruun-Olsen et al. reported superior improvement of postoperative flexion ROM in the CPM plus active-exercise group relative to the active-exercise-only group <sup>[11]</sup>. However, the Cochrane systematic review indicated that CPM combined with conventional physiotherapy only yields modest short-term ROM benefits without significant long-term functional improvement <sup>[12]</sup>. In recent years, deeper understandings have been gained regarding clinical indication and intensity regulation of CPM <sup>[13]</sup>. Therefore, CPM should be regarded as an adjunct to active training and implemented under pain-controllable conditions, and can never substitute active physical exercise.

### **3.3. Active joint range-of-motion training**

Progressive active knee flexion-extension training is initiated 2–3 days after surgery, including bedside leg-dangle exercise, seated knee flexion, supine knee-hugging and wall-sliding training. Exercises should follow a step-wise principle, with knee flexion angle increased day-by-day within pain-free or mildly-tolerable pain thresholds. Meanwhile, extension-limitation correction can be achieved by placing a pillow beneath the heel for knee-pressing or prone suspension leg compression. Terminal-range extension training generates definite efficacy for mild extension lag within 10°. Violent passive manipulation must be avoided during training, for fear of soft-tissue injury, hematoma formation or even periprosthetic fracture. When ROM improvement plateaus, patellar mobilization together with stretching of quadriceps and hamstrings can be adopted as auxiliary interventions.

## **4. Roles of muscle-strength training and proprioceptive training**

### **4.1. Quadriceps-strength training**

Quadriceps strength is universally markedly diminished after TKA. Extensor-apparatus muscle strength is closely correlated with knee stability, flexion-extension coordination and maintenance of joint ROM. Mizner et al. verified that pre-operative quadriceps strength serves as an independent predictor of functional outcomes one-year post-operation <sup>[14]</sup>. Commonly adopted training modalities include isometric contraction, multi-directional straight-leg raise, terminal-range knee extension, and progressive resistance training (elastic bands, sandbags, isokinetic training). Adequate strength training for quadriceps and hamstrings can ameliorate extension limitation, mitigate quadriceps inhibition, supply dynamic support for flexion training, and facilitate conversion of passive range of motion into functionally-available active range of motion.

### **4.2. Proprioception, balance and gait training**

During TKA, the anterior cruciate ligament is resected and proprioceptors embedded within joint capsule and surrounding soft tissues are disturbed, resulting in remarkable deterioration of knee position sense and

kinesthesia. Neuromuscular training consisting of balance-pad/balance-board exercises, single-leg stance, weight-shift drills and closed-chain exercises can enhance proprioception and dynamic balance capacity, rectify pathological gait, and improve functional utilization of acquired ROM <sup>[15]</sup>. Power cycling (gradually lowering saddle height), step ascending-descending and wall-squat exercises can be sequentially introduced at postoperative week 4-6, so as to achieve synchronized promotion of range of motion, muscle strength and motor coordination.

## **5. Impacts of pain management and swelling control on joint range of motion**

Pain and swelling constitute primary obstacles restricting postoperative ROM training. Pain provokes protective muscle inhibition and joint immobilization, thus establishing a vicious cycle of “pain-immobilization-adhesion-joint stiffness”. Peri-operative multi-modal analgesia (stratified administration of paracetamol, non-steroidal anti-inflammatory drugs, opioids, together with peri-articular injection) combined with swelling-control measures such as post-incision ice-packing, limb elevation and elastic bandage compression can greatly boost patients’ training tolerance and compliance <sup>[16]</sup>. ROM training can obtain effective angle increment only under sufficient analgesia. Blind pursuit of larger angles ignoring pain control frequently leads to training phobia and functional regression.

## **6. Synergistic application of Mongolian traditional therapies and modern rehabilitation training**

In Mongolian medicine, knee osteoarthritis is categorized as “joint Shar-Us disease (Huang-Shui disease)”. Its pathogenesis is attributed to disturbance of San-Gen (three fundamental body constituents), excessive Huang-Shui (yellow fluid) accumulation and impeded qi-blood circulation. Therapeutic principles include regulating body constitution, drying Huang-Shui, dredging Bai-Mai (white vessels), activating blood circulation and relieving pain <sup>[17]</sup>. After TKA, standardized rehabilitation training can be complemented by characteristic external Mongolian-medicine therapies:

- (1) Five-Flavor-Nectar medicinal bath and topical Mongolian-medicine compress, to warm meridians, unblock collaterals, reduce swelling and alleviate pain;
- (2) Mongolian moxibustion and Mongolian-medicine acupuncture, for relief of quadriceps spasm and per-incision pain <sup>[18]</sup>;
- (3) Cupping and blood-letting therapy, indicated for middle-late postoperative phase with local stasis, swelling and pain;
- (4) Mongolian-medicine traditional massage and joint-mobilization manipulation, to improve soft-tissue extensibility and assist ROM recovery.

The above-mentioned therapies possess unique strengths in mitigating postoperative pain-swelling and improving rehabilitation compliance, serving as a complement to modern rehabilitation. Nevertheless, indications and intervention timing must be strictly controlled; blood-letting and deep massage with strong stimulation are contraindicated in early postoperative phase with bleeding tendency. Integrating Mongolian-medicine rehabilitation techniques into multi-modal TKA postoperative rehabilitation pathways represents a valuable exploration combining ethnic-medicine practice and modern rehabilitation medicine.

## 7. Problems and prospects

Although the clinical value of TKA postoperative rehabilitation is well-recognized, multiple challenges remain unsolved.

- (1) Uniform standardized rehabilitation protocols are lacking; controversies persist concerning training timing, intensity and progression. Post-discharge rehabilitation organization and supervision remain insufficient; systematic reviews report limited evidence quality for post-discharge physiotherapy<sup>[19]</sup>.
- (2) Research focusing on individualized and telerehabilitation models for pastoral-area patients with scattered residence and difficult follow-up is inadequate.
- (3) High-quality evidence-based research for Mongolian-medicine-based rehabilitation therapies is scarce.

Future research should carry out multi-center, large-sample randomized controlled trials, adopt wearable devices and digital platforms to realize objective quantitative monitoring of ROM and remote rehabilitation guidance, thoroughly evaluate clinical efficacy and health-economic value of integrated Mongolian-Western-medicine rehabilitation pathways, and gradually formulate TKA postoperative rehabilitation specifications suitable for national conditions in China.

## 8. Conclusions

Restoration of ROM after TKA results from combined effects of surgical technique, pain management, rehabilitation training and patient-related factors. Among these components, standardized systematic rehabilitation training delivers the most modifiable and direct clinical benefits. Rehabilitation regimens complying with principles of early intervention, gradual progression, active-exercise priority, passive-exercise supplementation, individualization and multi-modal intervention can effectively improve knee flexion-extension ROM, lower the incidence of joint stiffness and adhesion, and accelerate functional recovery. Clinicians should establish the conception of full-course peri-operative rehabilitation, attach importance to pre-operative pre-rehabilitation and patient health education, maximize synergistic advantages of modern rehabilitation techniques and characteristic ethnic-medical therapies, and ultimately maximize restoration of patients' joint function and quality of life<sup>[20]</sup>.

## Disclosure statement

The author declares no conflict of interest.

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