ACRM AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2019;■:■■■-■■■

REVIEW ARTICLE (META-ANALYSIS)

Continuous Passive Motion After Total Knee Arthroplasty: A Systematic Review and Meta-analysis of Associated Effects on Clinical Outcomes

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Abstract

Objective: To evaluate the efficacy of continuous passive motion (CPM) after total knee arthroplasty (TKA) and whether the use of CPM is related to improved clinical and functional outcomes.

Data Sources: A systematic MEDLINE search via Web of Science, Cochrane Library, and PubMed databases was conducted.

Study Selection: English-language articles published between January 2000 and May 2018 reporting the related clinical outcomes of CPM after TKA were included. A total of 3334 titles and abstracts were preliminarily reviewed, of which 16 studies were included according to the eligibility criteria.

Data Extraction: Two different reviewers were selected to perform the study extraction, independent of each other. If there were any disagreements regarding the final list of studies, the third reviewer reviewed the list as an arbitrator for completeness.

Data Synthesis: A total of 16 trials with 1224 patients were included. The pooled results revealed that use of CPM did not show a statistically significant improvement of postoperative knee range of motion (ROM) except for middle-term passive knee extension and long-term active knee flexion ROM. Also, CPM therapy did not show a significant positive effect on the functional outcomes. No significant reduction in length of stay (LOS) and incidence of adverse events (AEs) was identified.

Conclusion: Among patients undergoing TKA, neither the ROM nor the functional outcomes could be improved by CPM therapy. Moreover, the risk of AEs and LOS could not be reduced by application of CPM. The current available evidence suggested that this intervention was insufficient to be used routinely in clinical practice.

Archives of Physical Medicine and Rehabilitation 2019;■:■■■-■■■

The rate of knee osteoarthritis (OA) and rheumatoid arthritis (RA) has steadily increased over the past decades, leading to severe pain, muscle weakness, and gait disturbance.[1] Total knee arthroplasty (TKA) has been regarded as a feasible and effective method for the treatment of knee OA and RA. The major aim of the TKA procedure was to achieve pain relief and recovery of knee function. To adapt to daily living activities, great attention should be paid to postoperative knee mobility or range of motion (ROM).[2] Rowe et al[3] found that limited knee ROM postoperatively may cause risk of falls and knee flexion >120° was appropriate for most daily activities. Therefore, continuous passive motion (CPM) was advocated to facilitate the recovery of knee function during postoperative rehabilitation.

Overall, there is extensive literature reporting that CPM following TKA was beneficial for optimal patient outcomes.[4-6] Bade et al[7] and Naylor et al[8] regarded CPM as a significant indicator and determinant of early functional outcomes during the initial postoperative stages. Harvey et al[9] performed a meta-analysis and pointed out that application of CPM has short-term influence on recovery of knee function and ROM to prevent postoperative knee impairments. In 2016, Liao et al proposed that early application of CPM with initial high flexion and rapid progress may have positive effect on knee function up to 6 months after surgery.[4]

However, Chen et al evaluated 51 such patients and categorized them randomly into 2 groups (CPM + physical therapy

Disclosures: none.

0003-9993/19/$36 - see front matter © 2019 by the American Congress of Rehabilitation Medicine
https://doi.org/10.1016/j.apmr.2019.02.001

group, physical therapy group).[10] They concluded that use of CPM appeared not to produce any added benefit for knee function of patients after TKA. Also, a 2015 systematic review showed that postoperative CPM failed to provide any advantages on recovery of knee mobility.[2] Thus, the aforementioned studies implied that the application of CPM was still under debate.

In addition to knee ROM and function, pain (analgesia requirements), wound healing, swelling, or potential adverse events (AEs) secondary to improper implementation of CPM were possible limiting factors and should be taken into consideration. The current study was conducted to present a systematic literature review and meta-analysis of the efficacy of CPM and associated complications for patients after TKA. Moreover, we intend to specifically answer the following questions: What is the impact of CPM on short-, middle-, and long-term knee functional outcomes? Does the use of CPM increase the prevalence of complications or AEs, such as pain, swelling, and wound healing failure? Is there any difference of length of stay (LOS) between patients with or without application of CPM postoperatively?

Method

Search strategy

A systematic MEDLINE search via Web of Science, Cochrane Library, and PubMed databases was conducted using combinations of the following terms: "total knee arthroplasty," "total knee replacement," "continuous passive motion," "motion therapy," "postoperative knee rehabilitation," and "RCTs"; "AND" and "OR" were also used to combine those terms to construct the searching strategy. English-language articles published between January 2000 and May 2018 reporting the related clinical outcomes of CPM after TKA were included. Case reports, editorials, and reviews without quantitative data were excluded. Primary surgical indications involving trauma, infection, or tumor for TKA were excluded. The reference lists focused on CPM after TKA were also assessed for eligible articles to expand search results.

Eligibility criteria

The inclusion criteria in the current meta-analysis included (1) randomized controlled trials (RCTs), (2) comparative control group (experimental and control groups), (3) published English language trials, (4) participants undergoing TKA. The physiotherapy intervention for both groups consisted of muscle-strengthening exercises, functional exercises, and gait training, while CPM was applied for only the experimental group.

List of abbreviations:

AE	**adverse event**
CPM	**continuous passive motion**
LOS	**length of stay**
KSS	**Knee Society Score**
WMD	**weighted mean difference**
OA	**osteoarthritis**
RA	**rheumatoid arthritis**
ROM	**range of motion**
TKA	**total knee arthroplasty**
TUG	**timed Up and Go**
WOMAC	**Western Ontario and McMaster University Osteoarthritis Index**

Study selection and data abstraction

Two different reviewers were selected to perform the study extraction, independent of each other. If there were any disagreements regarding the final list of studies, the third reviewer reviewed the list as an arbitrator for completeness.

The major categories of variables included (1) patient demographics, (2) characteristics of trials, (3) outcome measurements. The patient demographics consisted of sex, age, number, diagnosis, and surgical approach. The characteristics of trials comprised authors, publication date, types of study, description of CPM, and physiotherapy treatment. The outcome measures for this study included ROM (active knee flexion/extension ROM and passive knee flexion/extension ROM), pain, function, swelling, LOS, and AEs.

The evaluation of knee function included Knee Society Score (KSS),[11] timed Up and Go (TUG),[12] and Western Ontario and McMaster University Osteoarthritis index (WOMAC)[13] among included studies. TUG as a functional test recorded the time for patients required getting up from a chair with armrests, walking 3 minutes, turning around, walking back to a chair, and sitting down.[14] WOMAC was a disease-specific scale consisting of pain, stiffness, and physical function subscales. The whole scale scores were 100, and higher values represented better function, less pain, and less stiffness.[15]

Risk of bias

The risk of bias in the trials was assessed by 2 authors using the Cochrane risk of bias tool. The 7 items were listed as follows: (1) random sequence generation (selection bias), (2) allocation concealment (selection bias), (3) blinding of participants and personnel (performance bias), (4) blinding of outcome assessment (detection bias), (5) incomplete outcome data (attrition bias), (6) selective reporting (reporting bias), (7) other bias. Each item is evaluated as high, low, or unclear. We dealt with the disagreements by discussion, consulting with the third researcher if necessary.

Statistical analysis

Meta-analysis was performed with the software Review Manager (RevMan) version 5.3.[a] The weighted mean differences (WMDs) and 95% CIs were used to present results for continuous data, while odds ratios and 95% CIs were used to present results for dichotomous outcomes.

Statistical heterogeneity of results between studies was examined using the I^2 statistic. For I^2, values of 25% to <50%, 50% to <75%, and ≥75% may be considered to represent small, medium, and large amounts of inconsistency, respectively.[16] A fixed effect model was applied for studies with $P>.10$ and $I^2<50\%$. A random effect model was used for studies with $P\le.10$ and $I^2\ge50\%$. Meta-analysis quantitative synthesis was not performed when the heterogeneity was large; thus, descriptive analysis was adopted. For the text for overall effect, a P value $\le.05$ was considered statistically significant.

Results

Search results

A total of 3334 titles and abstracts were preliminarily reviewed, of which 16 studies were included according to the eligibility criteria. The study selection process is summarized in figure 1. These studies were all RCTs.

Study characteristics and quality

Sixteen RCTs directly comparing clinical outcomes for 1224 OA and RA patients with or without CPM after TKA were included in this meta-analysis. All of the included studies had defined eligibility criteria. The baseline information of these studies is listed in table 1. These studies were evaluated with the risk of bias, and the outcome is shown in figure 2.

Outcome analysis

Active knee flexion ROM (short-, middle-, and long-term)

Short-term active knee flexion ROM was available in 8 studies. Random effect model was used to analyze the pooled data. The results showed that no significant difference was identified between the 2 groups (WMD, 0.48; 95% CI, −1.73 to 2.70; $P=.67$). There was evidence for statistically significant heterogeneity ($I^2=45\%$; $P=.08$) (fig 3A).

Middle-term active knee flexion ROM was available in 4 studies. Fixed effect model was used to analyze the pooled data. Overall, the ROM was similar for both groups (WMD, 1.21; 95% CI, −0.98 to 3.41; $P=.28$). Chi-square tests indicated no statistical evidence of heterogeneity ($I^2=43\%$; $P=.15$) (fig 3B).

Long-term active knee flexion ROM was reported in 1 study by Huang et al, yielding significant 5° higher postoperative active knee flexion ROM in the CPM group than those in the non-CPM group at 1-year follow-up.

Passive knee flexion ROM (short-, middle-, and long-term)

Details regarding short-term passive knee flexion ROM was available in 4 studies. Fixed effect model was used to analyze the pooled data. Overall, the WMD was equivalent for both the

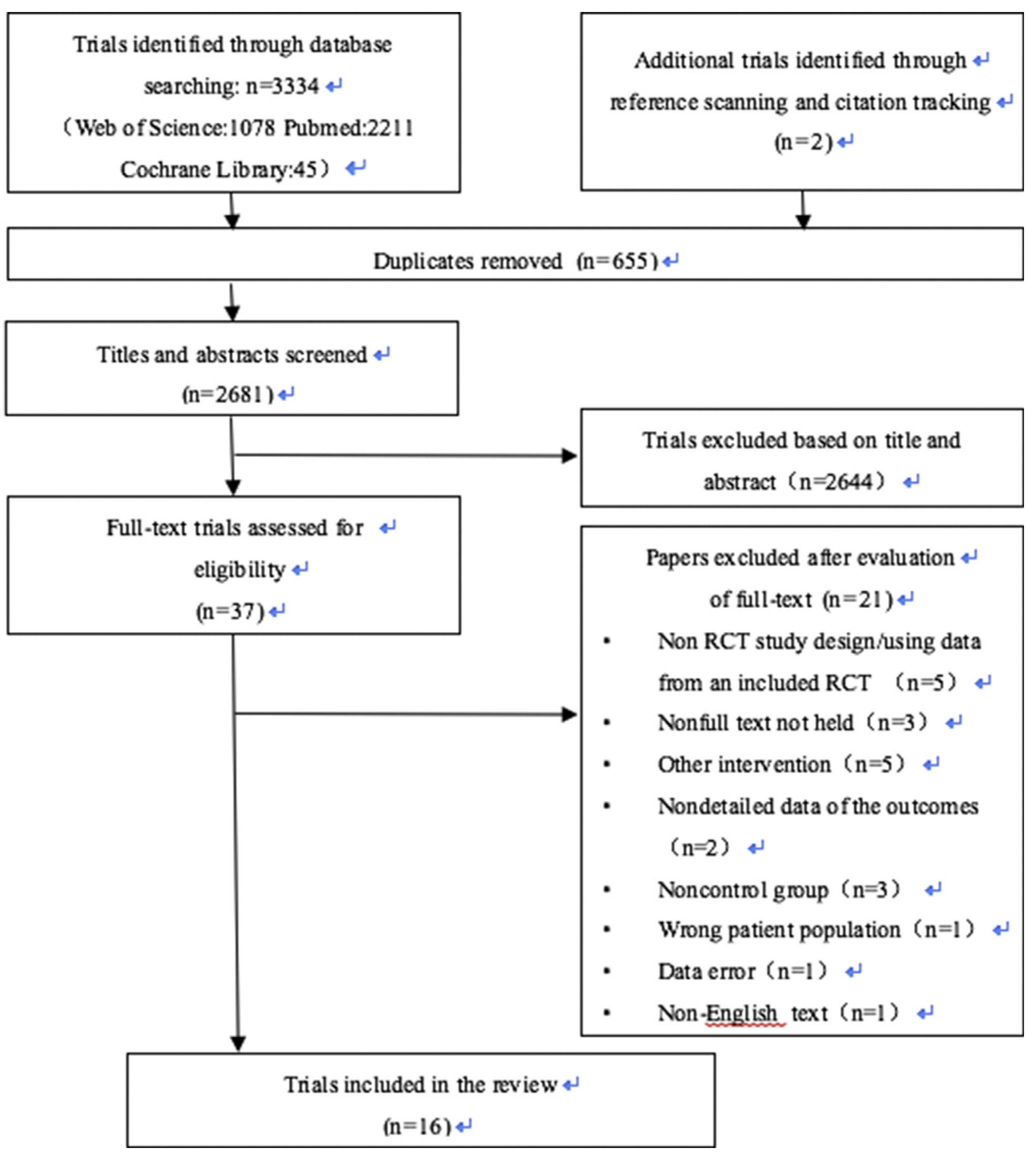

Fig 1 Flow diagram showing the process of literature selection.

Table 1 Characteristics of included studies

Author	Participants	Interventions	Assessment Time/Outcomes
Chen et al[17]	■ Sample size: Study group = 23 Control group = 28 ■ Mean age (y): Not described ■ Sex, F (%): Study group = 73.9 Control group = 67.9	■ Study group: CPM + physical therapy. Start: Set up by the treating therapist within 24 h of admission. Range: Initially set from 0° of extension to 10° less than the measured passive knee flexion. Increase: Increased daily by the therapist as tolerated by the patients. Duration: Provided for 5 h/d. Endpoint: Not described. ■ Control group: Physical therapy. Not described.	■ Admission ■ Third and seventh day after admission ■ Discharge ■ ROM-passive knee flexion ■ ROM-passive knee extension ■ Knee circumference
MacDonald et al[18]	■ Sample size: Study group = 40 Control group = 40 ■ Mean age (y): Not described ■ Sex, F: Not described	■ Study group: CPM + physical therapy. Start: CPM commenced POD 0. Range: Initially 0°-50°. Increase: Increased by 10°/h as tolerated. Duration: Provided for 18-24 h/d. Endpoint: Continued until POD 1. ■ Control group: Physical therapy. Commenced on POD 0, twice daily for 6 wk, included active flexion and extension and passive ROM exercises. All patients were mobilized as tolerated using a walker or crutches.	■ Preoperative ■ 6 wk, 52 wk after surgery ■ Function (Knee Society Score) ■ ROM-passive knee flexion ■ ROM-passive knee extension ■ Length of stay ■ Pain medication
Beaupré et al[19]	■ Sample size: Study group = 40 Control group = 40 ■ Mean age (y): Study group = 69±8 Control group = 68±9 ■ Sex, F (%): Study group = 30 Control group = 52.5	■ Study group: CPM + physical therapy. Start: CPM commenced POD 2. Range: Initially 0°-30°. Increase: Increased as tolerated. Duration: Provided for three 2 h/d. Endpoint: Not described. ■ Control group: Physical therapy. Commenced on POD 7; 30 min/session, included walking within parallel bars or with a walker or crutches to each subject's tolerance. Knee active ROM exercises, short-arc quadriceps femoris muscle exercises without resistance, isometric knee extension exercises, straight leg raises without resistance, and instruction in stair climbing were started 4 d after the operation. Ice was applied before and after treatment each day.	■ Preoperative ■ Discharge ■ 5-7 d, 3 mo, 6 mo after surgery ■ ROM-active knee flexion ■ ROM-active knee extension ■ WOMAC (pain, stiffness, function) ■ SF-36
Can and Alpaslan[20]	■ Sample size: Study group = 16 Control group = 16 ■ Mean age (y):	■ Study group: CPM + physical therapy.	■ POD 1 ■ 3 wk after surgery (at discharge)

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Table 1 (*continued*)

Author	Participants	Interventions	Assessment Time/Outcomes
	Study group = 61.59±1.48 Control group = 63.12±1.72 ▪ Sex, F (%): Study group = 100 Control group = 100	Start: Set up by physiotherapist in the recovery room as soon as possible after surgery. Range: Extension = 0°; Flexion = 25°-30°. Speed: 2-3 cycles/min (approximately 4°-6°/s). Increase: Flexion = 5°-10°/d; Extension = Always set to 0; Speed: Progressively increased according to the flexion angle and patients tolerance. The maximal speed was 6 cycles/min (approximately 12°-14°/s). Duration: 4-6 h/d. Endpoint: Before discharge or when 90° of knee flexion was reached. ▪ Control group: Physical therapy. Commenced on POD 1; 1 h/d, lasted for 3 wk, included isometric quadriceps and gluteal exercises, ankle pump, straight leg raise, active-assisted and passive knee flexion-extension exercises, gentle hamstring stretching and ambulation, terminal extension, and prone knee flexion exercises, proprioceptive neuromuscular facilitation exercises, and progressive resistive exercises.	▪ 3 mo after surgery ▪ Pain (VAS) ▪ Pain (Knee Society System)
Huang et al[21]	▪ Sample size: Study group = 23 Control group = 21 ▪ Mean age (y): Combined = 69 ▪ Sex, F (%): Combined = 82	▪ Study group: CPM + physical therapy. Start: CPM commenced POD 0. Range: Initially 0°-40°. Increase: Increased by 10° each day until it was 90° on the sixth day, all at a moderate rate (4 r/min). Duration: Provided 20 h for the first 3 d and then 16 h for the remaining days. Endpoint: Continued until POD 4. ▪ Control group: Physical therapy. Commenced on POD 0, included isometric quadriceps and gluteal sets, ankle dorsiflexion and plantar flexion, assisted straight leg raising performed for the first 24 h. From the second day on, gentle hamstring stretching, short-arc quadriceps strengthening, passive, active, active-assisted knee flexion were performed.	▪ POD 7, POD 10, POD 14 ▪ 6 wk, 3 mo, 6 mo, 1 y after surgery ▪ ROM-active knee flexion ▪ ROM-active knee extension ▪ Adverse events: postoperative complications ▪ Length of stay
Bennett et al[22]	▪ Sample size: Study group = 48 Control group = 52 ▪ Mean age (y): Study group = 71.4 Control group = 71.1	▪ Study group: CPM + physical therapy Start: CPM commenced POD 0. Range: Initially 50°-90°. Increase: Increased 20° flexion/d.	▪ 5 d, 3 mo, 1 y after surgery ▪ ROM-active knee flexion

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Table 1 (*continued*)

Author	Participants	Interventions	Assessment Time/Outcomes
	■ Sex, F (%): Study group = 64.6 Control group = 67.3	Duration: Provided for 6 h/d. Endpoint: Continued until POD 5. ■ Control group: Physical therapy. Commenced POD 1; 1 h/d. Included ankle dorsiflexion/ plantar flexion active, assisted ROM, stretches, gait training, static quads, inner ROM quads, splint, transfer training, gait reeducation.	■ Pain (VAS) ■ Function (Knee Society Score) ■ Quality of life (SF-12 - Physical) ■ Wound Healing ■ ROM-passive knee flexion ■ ROM-active knee extension ■ ROM-passive knee extension ■ Length of stay
Denis et al[23]	■ Sample size: Study group = 28 Control group = 27 ■ Mean age (y): Study group = 68.4±7.4 Control group = 67.1±7.6 ■ Sex, F (%): Study group = 46.4 Control group = 51.9	■ Study group: CPM + physical therapy. Start: CPM commenced POD 2. Range: Initially 35°-45° flexion. Increase: Increments determined by therapist. Duration: Provided for 2 h/d. Endpoint: Continued until discharge or day 7 or 8. ■ Control group: Physical therapy. Commenced POD 1, included respiratory and circulatory exercises, isometric knee extensor muscle exercises, and extension knee alignment, active and passive knee flexion, abduction and adduction of the hip in the horizontal plane, knee extensor muscle exercises. Teaching for transferring and walking with the appropriate device was begun. Functional exercises with weight bearing were added on day 4. Management of stairs, if needed, was performed on day 6 or 7 before discharge.	■ Preoperative ■ Discharge ■ ROM-active knee flexion ■ Pain (WOMAC) ■ Function (timed Up and Go test) ■ Manipulation under anesthesia: closed manipulation ■ Adverse events: postoperative complications ■ ROM-active knee extension ■ Length of stay ■ WOMAC-stiffness and functional difficulty ■ Theoretical length of hospital stay ■ Frequency and intensity of physical activity
Lenssen et al[24]	■ Sample size: Study group = 30 Control group = 30 ■ Mean age (y): Study group = 64.1±8.1 Control group = 65±9.1 ■ Sex, F (%): Study group = 60 Control group = 70	■ Study group: CPM + physical therapy. Start: CPM commenced when discharge from acute hospital care (approximately POD 4). Range: Initial settings individually determined. Increase: Increased as tolerated. Duration: Provided for 4 h/d. Endpoint: Continued until POD 17. ■ Control group: Physical therapy. Commenced on POD 4, provided for 20 min/d, continued until 2 wk after hospital discharge. Included active ROM, passive ROM exercises, inner ROM and static quads strengthening, gait training (including stairs), sit to stand training.	■ POD 17, 6 wk, 3 mo after surgery ■ ROM-active knee flexion ■ Pain (WOMAC) ■ Function (Knee Society Score) ■ Participants' global assessment of treatment effectiveness: perceived effects ■ Manipulation under anesthesia: closed manipulation ■ ROM-passive knee flexion ■ ROM-active knee extension ■ ROM-passive knee extension ■ Pain, function (WOMAC, Knee Society Score) ■ Pain medication, ■ Satisfaction with treatment ■ Satisfaction with treatment results ■ Adherence to treatment protocol and use of CPM ■ WOMAC (stiffness and difficulty subscale)

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Table 1 (*continued*)

Author	Participants	Interventions	Assessment Time/Outcomes
Bruun-Olsen et al[12]	■ Sample size: Study group = 30 Control group = 33 ■ Mean age (y): Study group = 68±10 Control group = 71±10 ■ Sex, F (%): Study group = 73 Control group = 67	■ Study group: CPM + physical therapy. Start: CPM commenced POD 0. Range: Initially set at 70°-100° for flexion on POD 0, then set at 0° to maximum 100° flexion. Increase: Increased as tolerated. Duration: Provided for 2 × 2 h on POD 0, then provided for 2 × 3 h/d. Endpoint: Continued until POD 7. ■ Control group: Physical therapy. Commenced POD 1; 30 min/d, continued until discharge at 1 wk. Included assisted and active flexion and extension of the hip/knee, active isometric contraction of the quadriceps, walking training using a high walker, rollator or crutches, and eventually climbing stairs on crutches.	■ 1 wk, 3 mo after surgery ■ ROM-active knee flexion ■ Pain (VAS) ■ Function (timed Up and Go test) ■ ROM-passive knee flexion ■ ROM-passive knee extension ■ Swelling: knee circumference ■ 40-m walk, up/down stairs
Alkireand Swank[25]	■ Sample size: Study group = 33 Control group = 32 ■ Mean age (y): Study group = 65.6 Control group = 66.9 ■ Sex, F (%): Study group = 62.5 Control group = 52.3	■ Study group: CPM + physical therapy. Start: CPM commenced POD 0. Range: Initially set at 70°-90° for flexion. Increase: Increasing extension by 10° over 4 h for a total of 6 h/d. Duration: Provided for 3 times daily for 3 d. Endpoint: Not described. ■ Control group: Physical therapy. Provided twice a day.	■ POD 1, POD 2 ■ 2 wk, 6 wk, 3 mo after surgery ■ Pain (WOMAC) ■ Function: Knee Society Function Score ■ Manipulation under anesthesia: closed manipulation ■ ROM-passive knee flexion ■ ROM-passive knee extension ■ Length of stay ■ Adverse events: postoperative complications ■ Swelling: midpatellar girth ■ WOMAC-function ■ WOMAC-stiffness ■ Drainage output ■ Need for blood transfusion
Maniar et al[26]	■ Sample size: Study group = 28 Control group = 28 ■ Mean age (y): Study group = 66.06 Control group = 67.42 ■ Sex, F (%): Study group = 92.9 Control group = 92.9	■ Study group: CPM + physical therapy. Start: CPM commenced POD 2. Range: Initially set at 0°-30° for flexion. Increase: Increasing 10° every 5 min. Duration: Provided 15 min/session and 2 sessions/d. Endpoint: Continued until POD 4. ■ Control group: Physical therapy. Commenced POD 0. Continued POD 4. Included foot and ankle pump exercises, active ROM, gait training, static quadriceps, inner ROM quads, gait and stair training, transfer training.	■ 3, 5, 14, 42, 90 d after surgery ■ Pain (VAS) ■ Active ROM ■ TUG values ■ Suprapatellar and calf girths ■ WOMAC ■ SF-12 scores ■ Wound healing
Chen et al[10]	■ Sample size:		

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Table 1 (*continued*)

Author	Participants	Interventions	Assessment Time/Outcomes
	Study group = 68 Control group = 39 ■ Mean age (y): Study group = 69.25±6.79 Control group = 69.46±8.17 ■ Sex, F (%): Not described	■ Study group: CPM + physical therapy. Start: CPM commenced POD 1. Range: Set to at least 70° as tolerated and to as much as 100° for flexion, the next day the machine was set at 100° flexion. Increase: Increased as tolerated. Duration: Provided for more than 6 h/d. Endpoint: Commenced POD 4. ■ Control group: Physical therapy. Commenced POD 1, provided for 30 min/d. Included assisted and active flexion and extension of the hip/knee, active isometric contraction of the quadriceps, straight leg raising training, walking with a high walker or crutches, and eventually climbing stairs on crutches.	■ Preoperative ■ 2, 6 wk, 3, 6 mo after surgery ■ ROM ■ Pain (VAS) ■ SF-36
Herbold et al[27]	■ Sample size: Study group = 70 Control group = 71 ■ Mean age (y): Combined = 72±7 ■ Sex, F (%): Combined = 70.2	■ Study group: CPM + physical therapy. Start: CPM commenced the admission date to the inpatient rehabilitation facility. Range: Set based on the maximum flexion tolerated, and the extension was set at 0°. Increase: Increased as tolerated. Duration: Provided for >2 h/d. Endpoint: Continued until discharge. ■ Control group: Physical therapy. Commenced the admission date to the inpatient rehabilitation facility, provided for 3 h/d.	■ Admission ■ The day prior to discharge ■ 1 wk after discharge ■ ROM-active knee flexion ■ ROM-active knee extension ■ Length of stay ■ Function (FIM, timed Up and Go test) ■ Girth measurement ■ WOMAC
Boese et al[28]	■ Sample size: Study group = 55 Control group = 54 ■ Mean age (y): Study group = 69.1 Control group = 68.3 ■ Sex, F (%): Study group = 69.1 Control group = 61.1	■ Study group: CPM + physical therapy. Start: CPM commenced immediately upon arrival to the orthopedic floor. Range: Moving from 0°-110° range of motion. Increase: Increased as tolerated. Duration: Continued daily for a minimum of 5 h/d as tolerated for a minimum of 2 d. Endpoint: Continued until 90° of active flexion was obtained. ■ Control group: Physical therapy. Commenced POD 1, twice daily therapy protocol included quad sets, short arc quads, long arc quads, hip abduction, straight leg raises, ankle pumps, and gluteal sets beginning on the first postoperative day. Patients were encouraged to rock in a rocking chair 4 times/d for 20 min to reduce joint stiffness.	■ Preoperative ■ POD 1, POD 2 ■ 3 wk after surgery ■ Hemoglobin changes ■ Pain (VAS) ■ Girth measurements ■ Length of stay ■ ROM-active range of motion

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Table 1 (*continued*)

Author	Participants	Interventions	Assessment Time/Outcomes
Joshi et al[29]	■ Sample size: Study group = 55 Control group = 50 ■ Mean age (y): Study group = 68.5±7.8 Control group = 70.5±8.7 ■ Sex, F (%): Study group = 76.4 Control group = 60	■ Study group: CPM + physical therapy. Start: CPM commenced POD 1. Range: Not described. Increase: Increased as tolerated. Duration: Provided for 6 h/d. Endpoint: Continued until discharge. ■ Control group: Physical therapy. Commenced POD 0 or POD 1, all patients received 1-on-1 physical therapy 2 times/d and an additional ambulation session with a mobility technician.	■ Preoperative ■ 6 wk, 3 mo after surgery ■ ROM ■ Complication ■ WOMAC ■ PAQ scores ■ Length of stay ■ Discharge location ■ Time required to satisfy the physical therapy discharge criteria ■ Cost
Baloch et al[30]	■ Sample size: Study group = 38 Control group = 38 ■ Mean age (y): Study group = 61.6±9.1 Control group = 65.5±7.9 ■ Sex, F (%): Study group = 84.2 Control group = 76.3	■ Study group: CPM + physical therapy. Start: CPM commenced POD 1. Range: Initially 0°-30°. Increase: Increasing 10° every day. Duration: Provided for 2 × 1 h/d. Endpoint: Continued until discharge. ■ Control group: Physical therapy. Commenced POD 1, twice a day. Included bed-to-chair mobilization, ambulation with walker, and isometric and isotonic quadriceps-strengthening exercises.	■ Preoperative ■ Discharge ■ ROM-knee flexion ■ Length of stay

Abbreviations: PAQ, Patient administered questionnaire; POD, postoperative day; SF-12, 12-item Short Form Health Survey; SF-36, 36-item Short Form Health Survey; VAS, visual analog scale.

experimental and control groups (WMD, −0.79; 95% CI, −3.40 to 1.81; $P=.60$). There was no obvious evidence for statistically significant heterogeneity ($I^2=27\%$; $P=.25$) (fig 4A).

Middle-term passive knee flexion ROM was recommended in 3 studies. Random effect model was used to analyze the pooled data. The WMD was similar for both the experimental and control groups (WMD, 1.16; 95% CI, −3.75 to 6.08; $P=.64$). Statistically significant heterogeneity existed among the studies ($I^2=59\%$; $P=.09$) (fig 4B).

The long-term passive knee flexion ROM was reported by MacDonald et al, in which 120 patients were randomly assigned to 3 groups according to the magnitude of CPM. At 6-week assessment, the mean flexion ROM for the 3 groups were 104°, 98°, and 101°, respectively, showing no statistical significance.

Active knee extension ROM (short- and middle-term)

Seven studies included reports of short-term active knee extension ROM. Fixed effect model was used to analyze the pooled data. The ROM was significantly higher in the experimental group compared with the control group (WMD, 0.62; 95% CI, 0.05-1.19; $P=.03$). Chi-square tests indicated no statistical evidence of heterogeneity ($I^2=36\%$; $P=.15$) (fig 5A).

Middle-term active knee extension ROM obtained in 5 studies were evaluated. The pooled analysis indicated that there was no significant difference between groups (WMD, −0.09; 95% CI, −1.51 to 1.32; $P=.90$). The significant heterogeneity ($I^2=68\%$; $P=.01$) may be ascribed to difference in initial time of motion (fig 5B).

Passive knee extension ROM (short-, middle-, and long-term)

Apart from middle-term passive knee extension ROM, no statistical significance was found between groups for short- and long-term parameters. The between-study heterogeneity was not statistically obvious for middle-term outcome ($I^2=39\%$; $P=.20$), and fixed effect model was applied to assess the effect sizes. Significant higher passive knee extension ROM was identified for patients with CPM after TKA in comparison to those without intervention (WMD, 1.67; 95% CI, 0.22-3.12; $P=.02$) based on the analysis of 2 studies (fig 6).

Pain

Evaluation for pain was reported in 9 studies involving 705 patients. WOMAC pain subscale was used for 5 studies, while visual analog scale was applied for 3 studies. KSS pain subscale was used in 1 study. No significant difference was found between control and experimental groups in all the literature from discharge to final follow-up period.

Swelling short- and middle-term

A total of 4 trials about swelling involving 311 patients were analyzed. The overall results suggested no significant effect on swelling with CPM for short- (WMD, −0.12; 95% CI, −0.96 to 0.71; $I^2=0\%$; $P=.77$) and middle-term (WMD, 0.72; 95% CI, −0.87 to 2.31; $I^2=30\%$; $P=.37$) (fig 7).

Function short-, middle-, and long-term

Short-term function assessment was recorded in 5 studies by KSS, TUG, or WOMAC function score. None of the RCTs showed an increase in improvement of knee function with use of CPM (fig 8A).

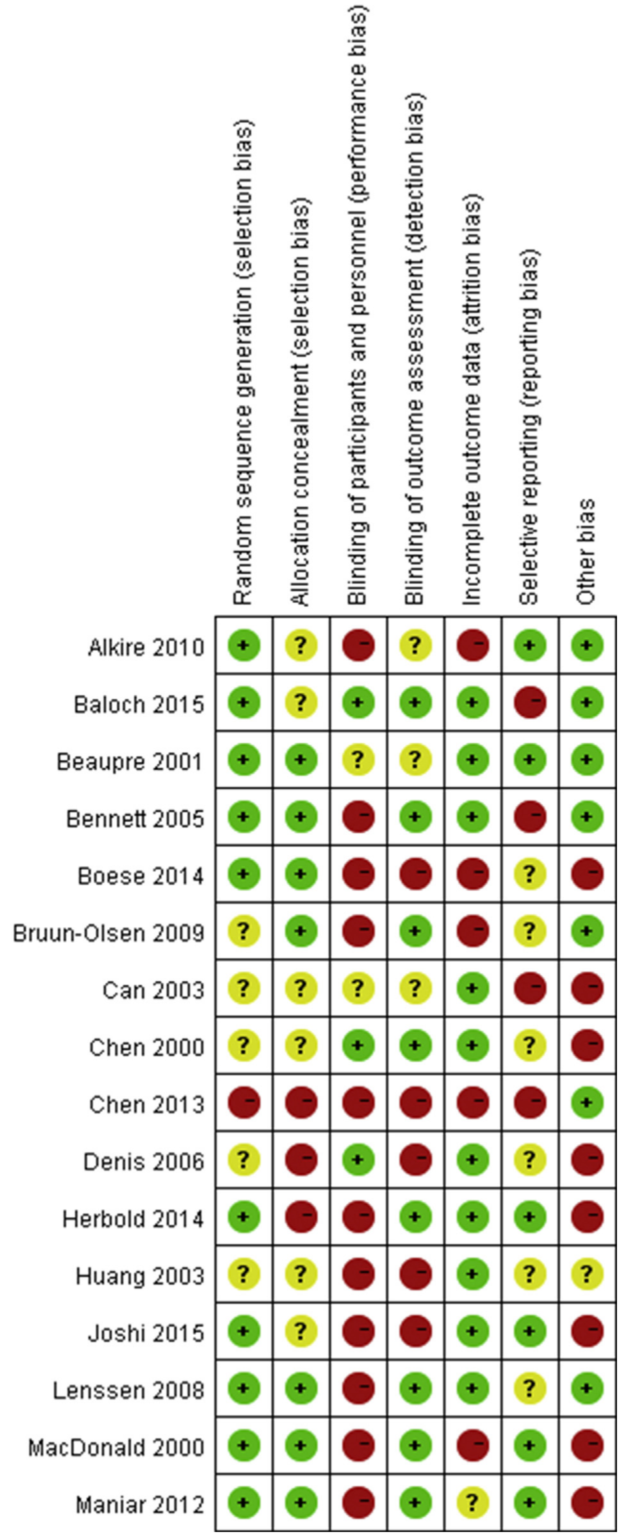

Fig 2 Risk of bias summary. The plus sign means low risk, the question mark means unclear risk, and the minus sign means high risk.

Regarding the middle- and long-term function, no statistically significant improvement was found with the use of CPM. (middle-term: WMD, 0.72; 95% CI, −2.76 to 4.19; $I^2=21\%$; $P=.69$; long-term: WMD, 0.87; 95% CI, −2.22 to 0.12; $I^2=87\%$; $P=.08$) (fig 8B).

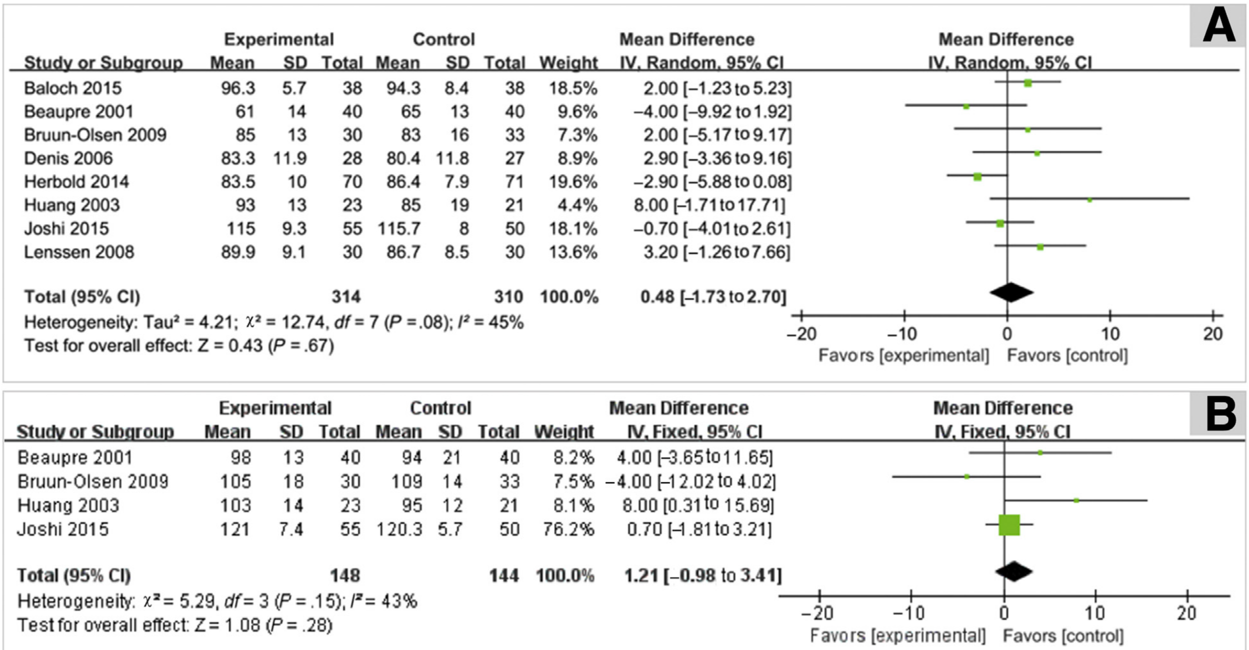

Fig 3 Forest plot for short- (A) and middle-term (B) active knee flexion ROM.

Length of hospital stay

Five trials involving 396 patients provided the available data about the LOS. The analysis did not show a statistically significant lower LOS in favor of CPM (WMD, −1.05; 95% CI, −2.22 to 0.12; $I^2=87\%$; $P=.08$) (fig 9A).

Adverse events

Five trials including 360 patients reported the incidence rate of AEs. The pooled risk ratio (0.62 in favor of CPM; 95% CI, 0.27-1.44; $I^2=0\%$; $P=.27$) showed no significant effect (fig 9B).

Discussion

Main findings

The current meta-analysis performed a systematic review of available literature. The overall results showed low- to moderate-quality evidence that application of CPM to patients undergoing TKA has no positive effect on improving the active or passive knee flexion ROM or active knee extension ROM. Remarkably, significantly higher middle-term passive knee extension and long-term active knee flexion ROM were found for patients with CPM than those without. Low-quality evidence

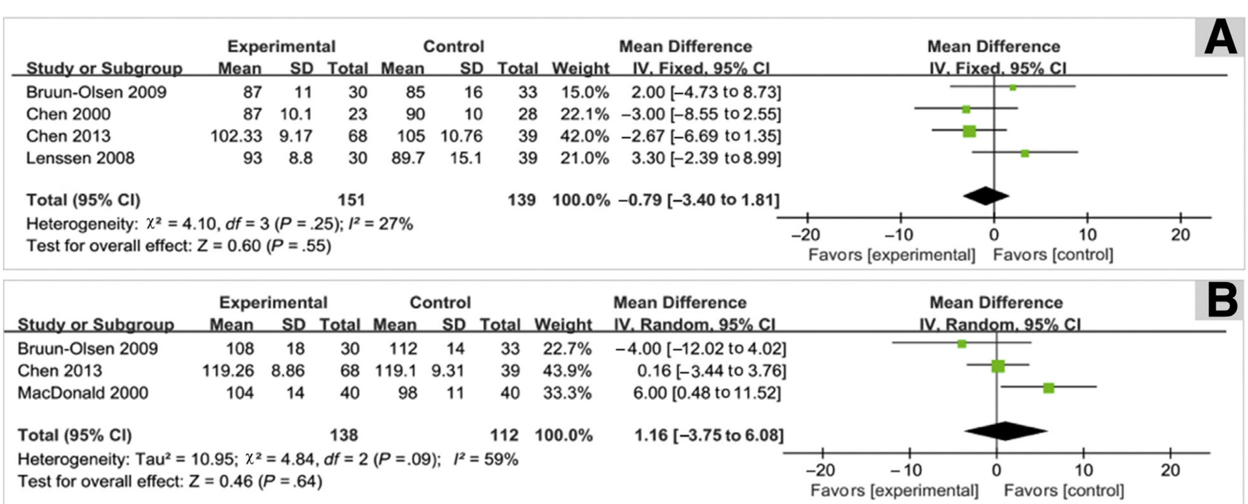

Fig 4 Forest plot for short- (A) and middle-term (B) passive knee flexion ROM.

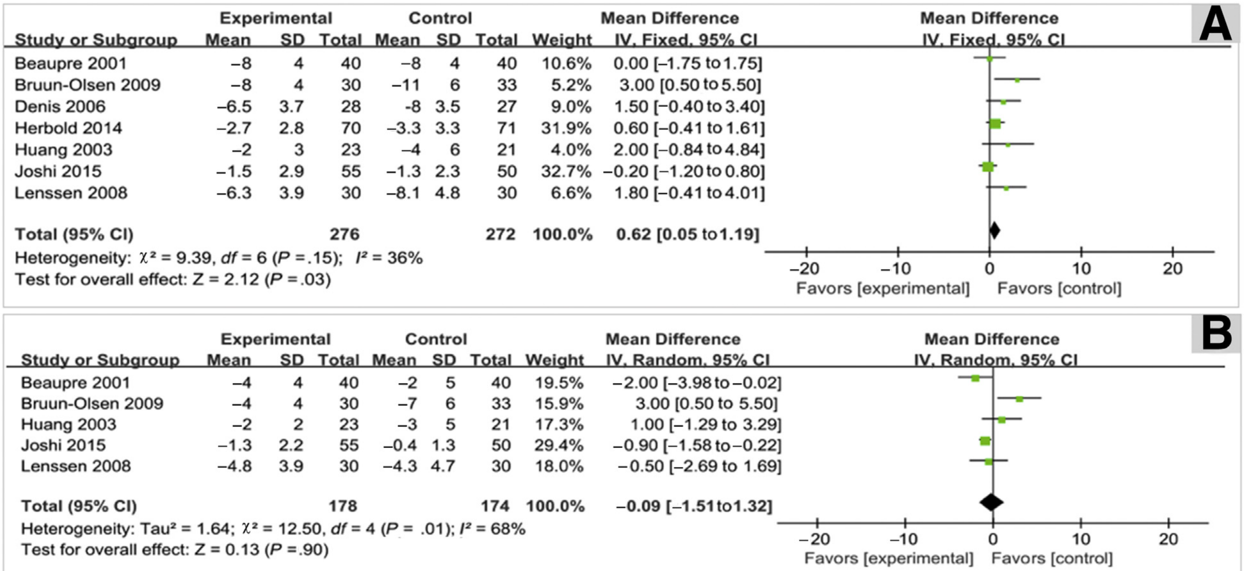

Fig 5 Forest plot for short- (A) and middle-term (B) active knee extension ROM.

indicated that CPM treatment may not have an advantage of improving the knee function and promoting the process of wound healing, thereby reducing the LOS. However, this study provided low to moderate evidence that the prevalence of AEs and swelling of the knee joint appear not to increase in the experimental group.

Overall effect on knee ROM and function

Our results were inconsistent with those of previous studies, which demonstrated that CPM was beneficial for recovery of knee function and accelerating the wound healing.[31,32] The reason was that more recent published systematic reviews were included and a larger

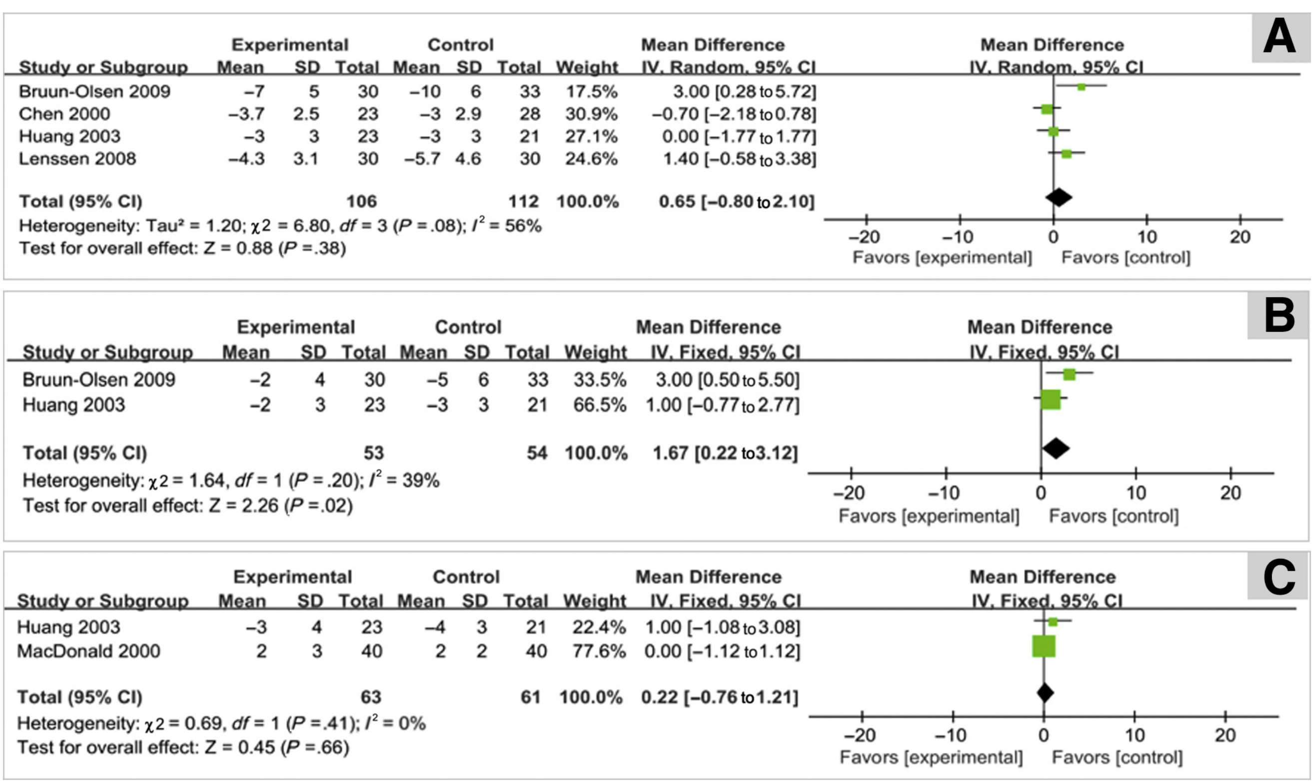

Fig 6 Forest plot for short- (A), middle- (B), and long-term (C) passive knee extension ROM.

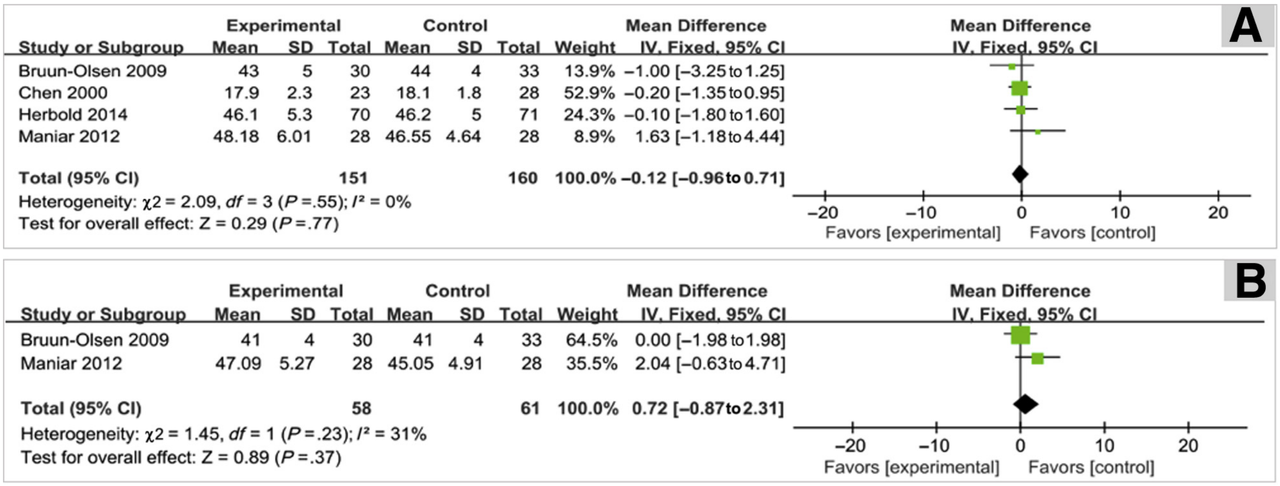

Fig 7 Forest plot for short- (A) and middle-term (B) swelling.

sample size was investigated. In the current study, only the middle-term passive knee extension and long-term active knee flexion ROM was significantly higher in favor of CPM. The possible mechanism may be ascribed to changes within joint components and tissue metabolism. Besides that, the increased intra-articular stress tolerance and nociceptive nerve ending adaption may result in the improvement in joint motion, which was assumed to increase the knee extension angle.[33,34] Knee function-associated outcomes appeared to be more critical in evaluating the feasibility of CPM because of a greater amount of parameters involved in our study, such as LOS, AEs, or swelling,. Based on the current evidence, an increase in knee ROM after CPM application without improvement in knee function and reduced risk of AEs was identified. Therefore, it should be concluded that CPM may not provide a clinical benefit for recovery. Also, only 1 study was included for assessment of long-term active knee flexion ROM, and the evidence may be not persuasive.[21]

Functional outcomes in all of the included studies were pre- and postoperative KSS, TUG, or WOMAC. The KSS represented an attempt to separate knee function assessment from overall patient functional status so that it was easy to use and convincing.[24] Similarly, the WOMAC Osteoarthritis Index was a questionnaire specific for knee osteoarthritis that was generally acknowledged to have good validity and reliability by previous studies.[35] Despite a mild improvement in scores, the difference was not significant even with a prolonged use of CPM at home, which was reported by Lenssen et al.[24] Denis et al[23] analyzed 55 patients with 2 different patterns of CPM (low and moderate intensity) and applied TUG as the functional outcome. TUG was supposed to be reliable and efficacious because it is easy to perform in the early postoperative period and has good correlation with the walking speed.[14,23] However, no difference was identified between groups at discharge, suggesting that adding CPM applications to conventional physical therapy may not favor better function recovery. Additionally, Bruun-Olsen et al[12] introduced the 40-m walking test for patients with or without CPM intervention after active exercise to assess the middle- and long-term functional outcomes.[36] However, CPM as an adjunct to postoperative active exercise was not found to have an extra positive effect during short-, middle-, or long-term follow-up.

In terms of postoperative pain, the WOMAC pain score of the control group and moderate intensity CPM group (CPM

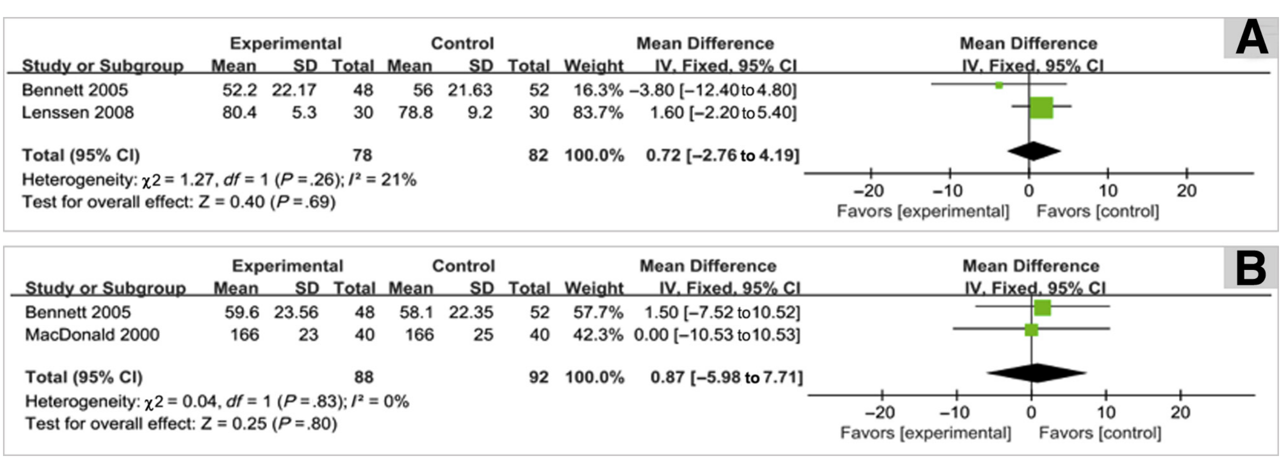

Fig 8 Forest plot for middle- (A) and long-term (B) function.

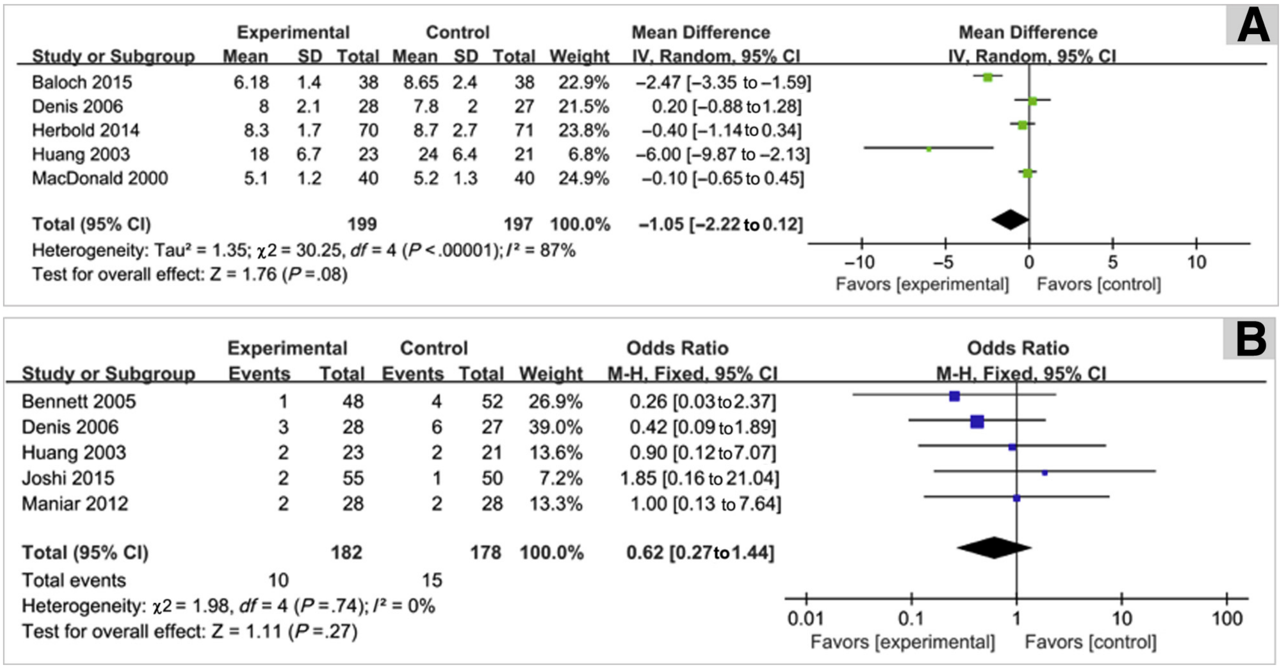

Fig 9 Forest plot for LOS (A) and AEs (B).

applications for 2 consecutive hours daily) were 39.8 and 27.7, respectively. It is noteworthy that the difference was nearly significant ($P = .07$), indicating that use of CPM may be beneficial for pain relief in the early postoperative stage.[23] The possible mechanism was the healing of structure surrounding the knee joint and rhythmic joint movements inhibiting the pain spasm reflex.[20,37]

Influence on prevalence of AEs

In the current study, the results showed that CPM application may not increase the overall prevalence of AEs.[21-23,26,29] Even so, some potential complications following use of CPM should be taken into consideration. Huang et al[21] reported 2 cases of superficial wound infection in the CPM group, while only 1 case occurred in the group without CPM. Also, scar bleeding was seen in 2 subjects of the experimental group in Denis's investigation.[23] The abovementioned complications may lead to wound healing failure. Regarding the assessment of wound healing, Maniar et al[26] introduced a detailed classification (soakage, spotting or staining, and normal dressing). They found staining in 7 patients of the 1-day CPM group and in 9 patients of the 3-day CPM group at postoperative day 3. Instead, there was only 4 patients presenting with wound staining in the control group. Hence, they concluded that use of CPM may tend to have a greater incidence of wound staining. Johnson et al[38] pointed out that the transcutaneous oxygen tension on the lateral aspect of incision may decrease as the knee flexed >40°. Thus, the range and intensity of joint movement should be controlled cautiously to decrease the risk of wound breakdown and prevent some rare AEs, such as acute quadriceps tendon tear, during CPM.

LOS after CPM

The LOS was related to the set of discharge criteria, and whether application of CPM can reduce the LOS is still under debate.[18,21,23,17,30] In the previous studies, the 90° knee flexion and functional activities were regarded as the discharge criterion. Block et al[39] introduced a modified criterion of a smaller ROM to accelerate discharge. Denis et al[23] also suggested active knee flexion ROM as one of the discharge criteria, which should be approximately 75°±5°. In the current study, no significant difference of LOS between the control and experimental groups should be attributed to the similar postoperative ROM and incidence of AEs. Although a significant increase of LOS in the CPM group was revealed in Baloch's investigation, it may be ascribed to their specific CPM protocol with which it takes a week to achieve a 90° flexion.[30] In addition, age, comorbidity, patient comfort, ambulatory status, basic physical condition, or independence level may have influence on the LOS.[17,19,25,28] Thus, the LOS appeared not to be decreased after additional CPM if all the aforementioned factors were considered.[23,30]

Study limitations

The results of the present study need to be interpreted regarding its limitations. First, the protocols for the CPM and the follow-up period were not uniform across all studies, which may lead to the possibility of bias. Second, the existing inherent heterogeneity among the included studies may affect the pooled analysis. Finally, the long-term outcomes for evaluation of CPM was lacking. Given these limitations, the conclusion of this meta-analysis should be adopted cautiously, and further trials are still warranted.

Conclusion

The evidence indicated that use of CPM was not frequently associated with improved knee ROM and functional outcomes from discharge to the final follow-up. Relative to non-CPM group, the application of CPM therapy was not superior with respect to the incidence of AEs and LOS. The results of the current study were inadequate to support the routine use of CPM to facilitate the recovery process.

Supplier

a. Review Manager (RevMan) version 5.3; Cochrane.

Keywords

Arthroplasty, replacement, knee; Length of stay; Meta-analysis; Motion therapy, continuous passive; Range of motion; articular; Rehabilitation

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