Original Article

Association of knee range of motion and continuous passive motion following total knee arthroplasty: a meta-analysis

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Background: Total knee arthroplasty (TKA) is considered a clinically effective intervention for knee arthritis. Continuous passive motion (CPM), one kind of rehabilitations following TKA, is usually identified to increase knee range of motion (ROM) and promote postoperative recovery of patients. Although many clinical trials have conducted, the results were controversial. Thus it is necessary to determine the effectiveness of CPM on ROM following TKA.

Methods: Randomized controlled trials (RCTs) describing CPM and ROM were obtained from the databases PubMed, Cochrane library and Excerpt Medical Database (EMBASE) up to May 2014. All analyses were conducted by Stata 12.0 software. Effect size was measured as standardized mean differences (SMD) with 95% confidence intervals (CIs). A random-effect model was selected to calculate the pooled SMD. Heterogeneity was assessed using the I^2 statistic with significance set at a P value less than 0.10. Subgroup analyses were performed based on CPM and standard physiotherapy. Publication bias was analyzed by Egger's test.

Results: Totally, nine RCTs were retrieved in this study. Meta-analysis showed that there were no significant differences between CPM and non-CPM treated patients in terms of active knee flexion ROM and active knee extension ROM at time of discharge from hospital, 6 weeks, 3 months, and more than 6 months respectively. Subgroup analyses showed no differences between CPM group and standard physiotherapy group.

Conclusions: CPM following TKA does not have clinical effects on postoperative recovery in aspect of active knee flexion ROM and active knee extension ROM at different treated times.

Keywords: Continuous passive motion (CPM); total knee arthroplasty (TKA); range of motion (ROM); meta-analysis

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Introduction

Arthroplasty is an orthopedic surgery done to restore the integrity and function of a joint, which can be restored by resurfacing the bones or be replaced by an artificial joint (1-3). Total knee arthroplasty (TKA) is considered a clinically effective intervention in recent years with high rates of success in treatment of chronic knee pain and disability (4,5). Due to knee stiffness after TKA, rehabilitation therapy plays an important role during the following treatments, which often includes continuous passive motion (CPM) (6).

In 1926, Von Riemke firstly stated that movement should be conducted slowly and continuously from the first day

after surgery (7). Then, Salter invented the concept of CPM based on a series of experiments and theories (8). CPM is a way to provide regular movement by a machine (7), and is usually identified to increase knee range of motion (ROM) (9). Hill *et al.* conducted a study to determine the effects of a CPM device on knee ROM after operation of intra-articular fractures around knee on 40 patients within 48 hours after surgery. They found that range of knee flexion was significant greater at 48 hour in CPM group than in non-CPM group (10). Moreover, CPM was also considered to decrease narcotic analgesics uses, to reduce the length of hospital stay (11) and to improve muscle strength (12). However, a randomized, controlled trial (including 160 patients) of CPM following TKA showed that CPM provided no benefit to patients recovering from TKA (13). Since CPM had a lot of uncertainties about the treatment effects after TKA, it is necessary to determine the effectiveness of CPM. Although many studies had been performed to evaluate the effectiveness of CPM following TKA, the results of these studies always seem inconsistent and inconclusive because of small sample size and uncertainties of the research subjects (14). Thus a meta-analysis is needed to integrate these data to better evaluate the therapeutic effect of CPM following TKA.

In present review, a series of randomized controlled trials (RCTs) were retrieved to determine the association between CPM and ROM (including both active knee flexion and active knee extension) following TKA before May 2014 and a meta-analysis was performed to evaluate the effectiveness of CPM following TKA.

Materials and methods

Literature search

Under the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement (15), a searching strategy was developed for present meta-analysis. Publications related to CPM and TKA were retrieved by searching the electronic databases of PubMed, Cochrane library and Excerpt Medical Database (EMBASE) up to May 2014. The search was based on combinations of the following items: continuous passive motion (or CPM), total knee arthroplasty, range of motion and range of movement.

Inclusion and exclusion criteria

Two investigators reviewed titles and abstracts matching the inclusion criteria independently. The inclusion criteria were as follows: (I) RCTs about the impact of CPM on ROM following TKA; (II) indexes such as active knee flexion ROM and active knee extension ROM; (III) papers including corresponding mean value and standard deviation; (IV) control groups treated by non-CPM measures (conventional measures such as motion, standard physical therapy and fixation). Studies were excluded if one of the following existed: (I) studies such as reviews, meeting summaries, case reports and comments; (II) studies only had mean value without corresponding standard deviation; (III) studies with repeated reporting articles and unclear described data; (IV) non-English literatures.

Data extraction

Data extraction was performed independently by two reviewers from all eligible studies according to the criteria listed above. Any disagreements were resolved by discussion with a third person. For each selected article in present study, the following characteristics were collected: the first author, year of publication, sample size, mean and standard deviation of active knee flexion in CPM group and non-CPM group respectively, mean and standard deviation of active knee extension in CPM group and non-CPM group respectively, and non-CPM treatments used in control groups.

Quality assessment

The Jadad scoring system was used to evaluate the quality of studies included in this meta-analysis (16). Jadad scores are based on the description of randomization (maximum score: 2 points), double blinding (maximum score: 2 points), and withdrawals and dropouts (maximum score: 1 points) and can range from 0 to 5 points. Higher score of Jadad indicates better methodological quality.

Statistical analysis

The statistical analysis was conducted using Stata 12.0 statistical software package. The effect sizes of continuous outcomes were measured as standardized mean differences (SMD) with 95% confidence intervals (CIs). A random-effect model was used to calculate the pooled SMD. Heterogeneity was examined by using the I^2 statistic (17) and P value <0.1 or I^2 >50% was considered heterogeneous. Subgroup analyses were performed between CPM group

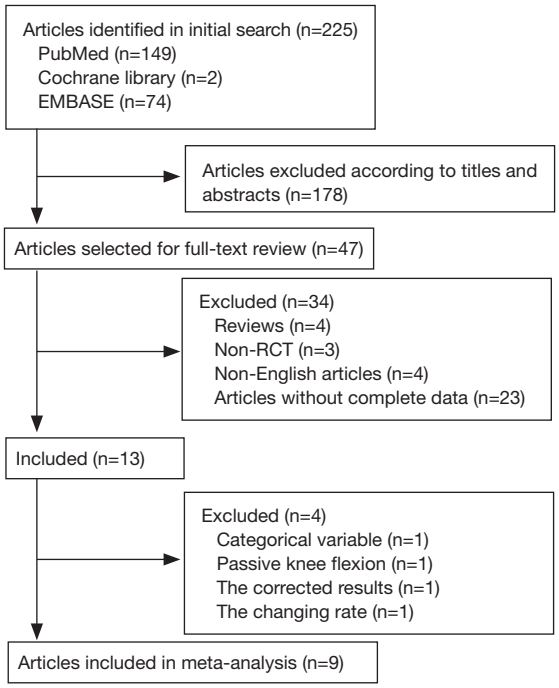

Figure 1 Study selection process and reasons for exclusion of studies.

and standard physiotherapy group. Results which cannot perform the meta-analysis were narrated descriptively. Finally, publication bias was assessed using the weighted regression tests described by Egger *et al.* (18). P<0.05 was considered statistically significant.

Results

Characteristics of selected literatures

A total of 225 articles were searched according to the key words, including 149 articles in PubMed, two articles in Cochrane library, and 74 articles in EMBASE. The titles and abstracts of these 225 articles were studied and 47 articles were selected for further analysis. Based on the full texts of the 47 articles, 13 articles were finally chosen, excluding four reviews, 23 articles without complete data, three non-RCTs, and four non-English articles. Among all the 13 articles, Davies's study (19) was removed because its outcome was a categorical variable; Chen's study (20) was removed because the outcome was based on passive knee flexion; Ritter's study (21) was removed because its results were corrected by repeated measures; Chiarello's study (22) was removed because the indexes used in this article were the change rate of ROM before and after the intervention (*Figure 1*). Finally, nine studies providing mean and standard deviation of active knee flexion and active knee extension respectively were included in this systematic review (23-31).

Table 1 summed up the characteristics of the selected literatures which were all RCTs from 1997 to 2014. The number of patients ranged from 53 to 210. Measurements of control groups were various. Among all the nine articles, five used standard physiotherapy (23-25,29,30); one used standard exercise (26); one used immobilization (28); one used active exercise (31); and one integrated immobilization and standard exercise (27).

The influence of CPM on active knee flexion at different time following TKA

Meta-analysis was performed to examine the association between CPM and active knee flexion ROM at different time following TKA (*Table 2*). For the outcomes of active knee flexion, there were no significant differences observed between CPM group and non-CPM group (including standard physiotherapy, standard exercise, immobilization, and active exercise) at the time of discharge from hospital (SMD =0.02, 95% CI: −0.40 to 0.43, P=0.941), 6 weeks (SMD =0.01, 95% CI: −0.30 to 0.33, P=0.933), 3 months (SMD =−0.11, 95% CI: −0.31 to 0.09, P=0.289), and more than 6 months (SMD =0.39, 95% CI: −0.34 to 1.12, P=0.297) respectively (*Figure 2*). Besides, statistically significant heterogeneity was observed at discharge (I^2 =80.9%, P=0.000, *Figure 2A*), 6 weeks after discharge (I^2 =69.8%, P=0.005, *Figure 2B*), and more than 6 months after discharge (I^2 =94.2%, P=0.000, *Figure 2D*), respectively. After subgroup analyses performed between CPM group and standard physiotherapy group (23-25,29,30), no heterogeneity was observed in the 3 times mentioned above respectively (*Table 2*, *Figures 2E-G*).

The influence of CPM on active knee extension at different time following TKA

For the outcomes of active knee extension, no significant differences were observed between CPM group and non-CPM group at the time of discharge from hospital (SMD =0.20, 95% CI: −0.02 to 0.41, P=0.075), 3 months (SMD =−0.13, 95% CI: −0.40 to 0.15, P=0.366), and more than 6 months (SMD =−0.13, 95% CI: −0.40 to 0.15, P=0.366) respectively. Meanwhile, heterogeneity also had no statistical differences at the 3 times respectively (*Figure 3*). The detailed information was shown in *Table 2*.

Table 1 Characteristics of the selected literatures of continuous passive motion against ROM after TKA

ID	Year	Study	Active knee flexion						Active knee extension				Time	Control
			CPM			Non-CPM			CPM		Non-CPM			
			Sample	Mean	SD	Sample	Mean	SD	Mean	SD	Mean	SD		
Discharge														
Herbold (24)	2014	RCT	70	83.5	10.0	71	86.4	7.90	–2.7	2.8	–3.3	3.3	Discharge	Standard physiotherapy
Denis [1] (25)	2006	RCT	26	78.7	10.6	27	80.4	11.80	–7.0	3.7	–8.0	3.5	Discharge	Standard physiotherapy
Denis [2] (25)	2006	RCT	28	83.3	11.9	27	80.4	11.80	–6.5	3.7	–8.0	3.5	Discharge	Standard physiotherapy
Beaupré (26)	2001	RCT	40	61.0	14.0	40	65.0	13.00	–8.0	4.0	–8.0	4.0	Discharge	Standardized exercises
Yashar (28)	1997	RCT	104	89.1	9.1	106	84.3	8.10	–	–	–	–	Discharge	Immobilization
6 weeks														
Lenssen (23)	2008	RCT	30	98.2	11.7	30	98.7	11.20	6.3	4.0	6.9	5.4	6 weeks	Standard physiotherapy
Lau (27)	2001	RCT	30	90.0	14.0	30	86.0	20.00	–	–	–	–	6 weeks	Immobilization
MacDonald [70–110] (29)	2000	RCT	40	101.0	13.0	40	104.0	14.00	–	–	–	–	6 weeks	Standard physiotherapy
MacDonald [0–50] (29)	2000	RCT	40	98.0	11.0	40	104.0	14.00	–	–	–	–	6 weeks	Standard physiotherapy
Worland (30)	1998	RCT	37	105.7	10.4	43	105.6	8.50	–	–	–	–	6 weeks	Standard physiotherapy
Yashar (28)	1997	RCT	104	104.8	2.3	106	103.6	2.70	–	–	–	–	6 weeks	Immobilization
3 months														
Bruun-Olsen (31)	2009	RCT	30	105.0	18.0	33	109.0	14.00	–4.0	4.0	–7.0	6.0	3 months	Active exercises
Lenssen (23)	2008	RCT	30	105.7	2.5	30	106.2	0.60	4.8	3.9	4.3	4.7	3 months	Standard physiotherapy
Beaupré (26)	2001	RCT	33	94.0	11.0	32	91.0	11.00	–4.0	4.0	–3.0	6.0	3 months	Standardized exercises
Yashar (28)	1997	RCT	104	107.7	1.7	106	108.2	4.70	–	–	–	–	12 weeks	Immobilization
≥6 months														
Lau (27)	2001	RCT	30	92.0	14.0	30	90.0	17.00	–	–	–	–	1 year	Immobilization
Beaupré (26)	2001	RCT	33	98.0	13.0	32	94.0	21.00	–4.0	4.0	–2.0	5.0	6 months	Standardized exercises
MacDonald [70–110] (29)	2000	RCT	40	112.0	8.0	40	112.0	9.00	2.0	2.0	2.0	3.0	52 weeks	Standard physiotherapy
MacDonald [0–50] (29)	2000	RCT	40	113.0	8.0	40	112.0	9.00	2.0	2.0	2.0	3.0	52 weeks	Standard physiotherapy
Worland (30)	1998	RCT	37	117.6	7.2	43	118.1	5.80	–	–	–	–	6 months	Standard physiotherapy
Yashar (28)	1997	RCT	104	113.0	0.5	106	110.5	1.81	–	–	–	–	1 year	Immobilization

ROM, range of motion; TKA, total knee arthroplasty; CPM, continuous passive motion; SD, standard deviation; RCT, randomized control trial.

Table 2 Influences of CPM on active knee flexion and active knee extension respectively at different time following TKA

The influence of CPM on active knee flexion at different time following TKA	Time	RCTs	No. of patients		Effect sizes			Heterogeneity		Subgroup analysis				
										Effect sizes			Heterogeneity	
			CPM	Non-CPM	SMD	95% CI	P	I^2 (%)	P	SMD	95% CI	P	I^2 (%)	P
Active knee flexion	Discharge	4	268	244	0.02	−0.40–0.43	0.941	80.9	0.000	−0.12	−0.45–0.21	0.459	36.5	0.207
	6 weeks	5	281	249	0.01	−0.30–0.33	0.933	69.8	0.005	−0.19	−0.42–0.04	0.101	0.0	0.434
	3 months	4	197	201	−0.11	−0.31–0.09	0.289	3.7	0.374	–	–	–	–	–
	≥6 months	5	284	251	0.39	−0.34–1.12	0.297	94.2	0.000	0.01	−0.24–0.27	0.916	0.0	0.826
Active knee extension	Discharge	3	164	138	0.20	−0.02–0.41	0.075	0.0	0.680	–	–	–	–	–
	3 months	3	93	188	0.16	−0.28–0.61	0.472	58.1	0.092	–	–	–	–	–
	≥6 months	3	113	112	−0.13	−0.40–0.15	0.366	10.0	0.329	–	–	–	–	–

CPM, continuous passive motion; TKA, total knee arthroplasty; RCT, randomized control trial; SMD, standardized mean differences; 95% CI, 95% confidence intervals.

Publication bias

For both active knee flexion and active knee extension, there were no significant differences between CPM group and non-CPM group at time of discharge from hospital, 6 weeks, and 3 months respectively (active knee flexion: P=0.436 for discharge, P=0.107 for 6 weeks after discharge, and P=0.861 for 3 months after discharge. Active knee extension: P=0.599 for discharge and P=0.438 for 3 months after discharge). However, the analyses of active knee flexion at 6 months after discharge showed publication bias (P=0.015), and no significance was observed after subgroup analysis (P=0.582).

Discussion

In present meta-analysis, a total of nine studies were included. For both active knee flexion ROM and active knee extension ROM, there were no significant differences between CPM group and non-CPM group at the time of discharge from hospital, 6 weeks, 3 months, and more than 6 months respectively. Thus it was concluded that CPM had no significant effects on active knee flexion and active knee extension of patients undergoing TKA, and the effectiveness was not changed by the therapy time (short-term or long-term).

Some other systematic reviews have been reported in previous studies. For example, Brosseau *et al.* conducted a meta-analysis to examine the effectiveness of CPM following TKA (14 studies containing 952 patients). Their results showed significant improvements in active knee flexion with the combined use of CPM and physiotherapy compared to physiotherapy alone. Meanwhile, length of hospital stay and time for knee manipulations were significant decreased in CPM group compared with those in physiotherapy group (32). Similarly, a meta-analysis by Lenssen *et al.* (including 15 articles) demonstrated that CPM, combining with standardized physical therapy after TKA, showed moderate, positive and short-term effects on postoperative recovery, but no relevant long-term effects (33). Du Plessis *et al.* performed a meta-analysis combining three RCTs and revealed that CPM can improve shoulder ROM (12). However, present analyses demonstrated that CPM had no effects on active knee flexion ROM and active knee extension ROM compared with the non-CPM therapy. Harvey *et al.* got the similar conclusion that the effects of CPM on knee ROM were too small to justify its use (20 RCTs containing 1,335 participants) (34). Because rehabilitation therapy following TKA was associated with various factors, many factors should be taken into account comprehensively to evaluate the effectiveness of CPM. In present review, only active knee flexion and active knee extension were performed meta-analysis, other indexes such as bleeding volume (35), degree of pain (36), swollen degree (37) and venous thrombus (38) were not included. Thus to be better understand the effectiveness of CPM following TKA, further studies should be proposed by integrating all the related indicators.

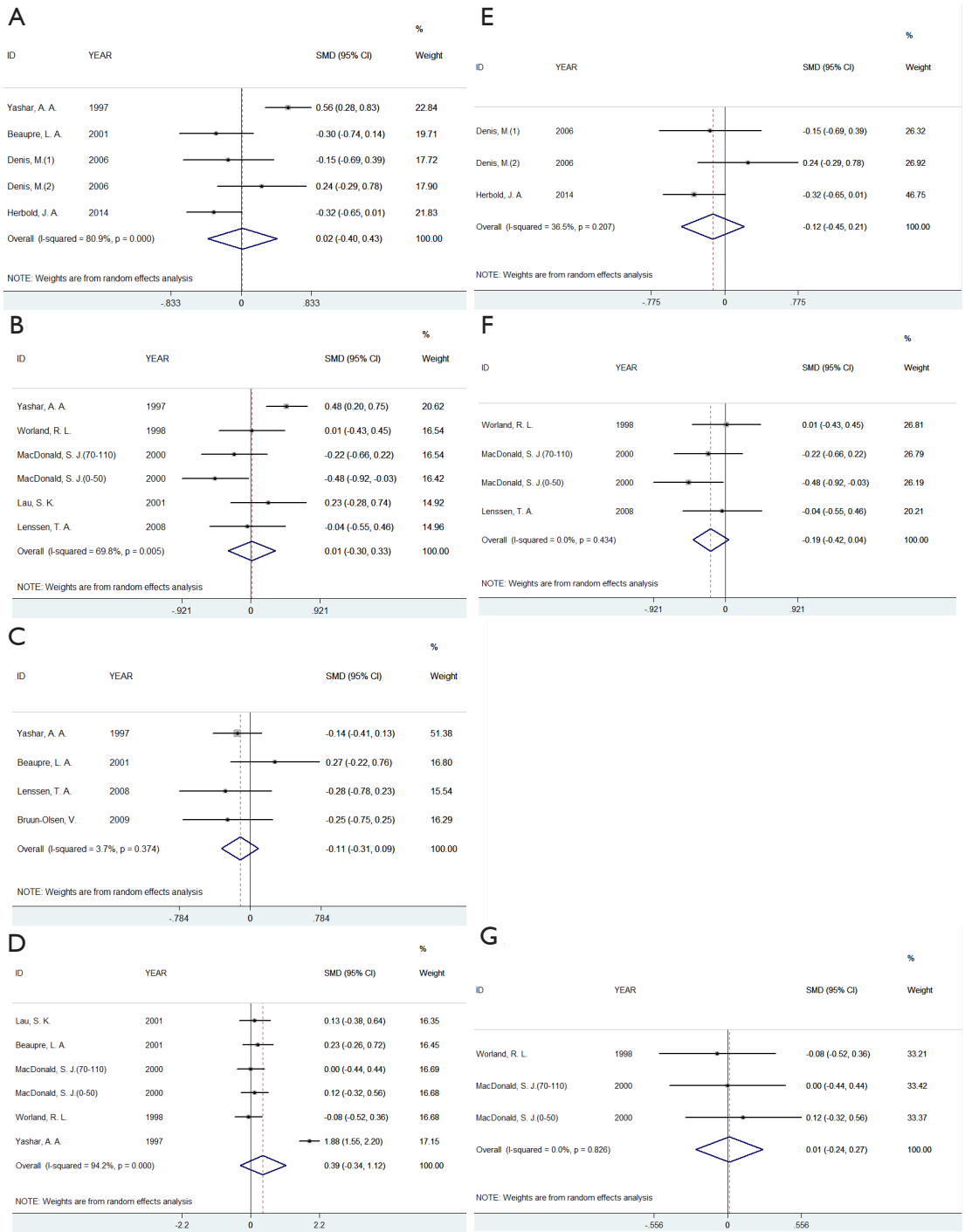

Figure 2 Active knee flexion ROM analyses after total knee arthroplasty (TKA) by meta-analysis. (A) Forest plot of ROM at discharge compared between CPM group and non-CPM group; (B) forest plot of ROM at 6 weeks after discharge compared between CPM group and non-CPM group; (C) forest plot of ROM at 3 months after discharge compared between CPM group and non-CPM group; (D) forest plot of ROM at more than 6 months after discharge compared between CPM group and non-CPM group; (E) forest plot of ROM at discharge compared between CPM group and standard physiotherapy group (subgroup analysis); (F) forest plot of ROM at 6 weeks after discharge compared between CPM group and standard physiotherapy group (subgroup analysis); (G) forest plot of ROM at more than 6 months after discharge compared between CPM group and standard physiotherapy group (subgroup analysis).

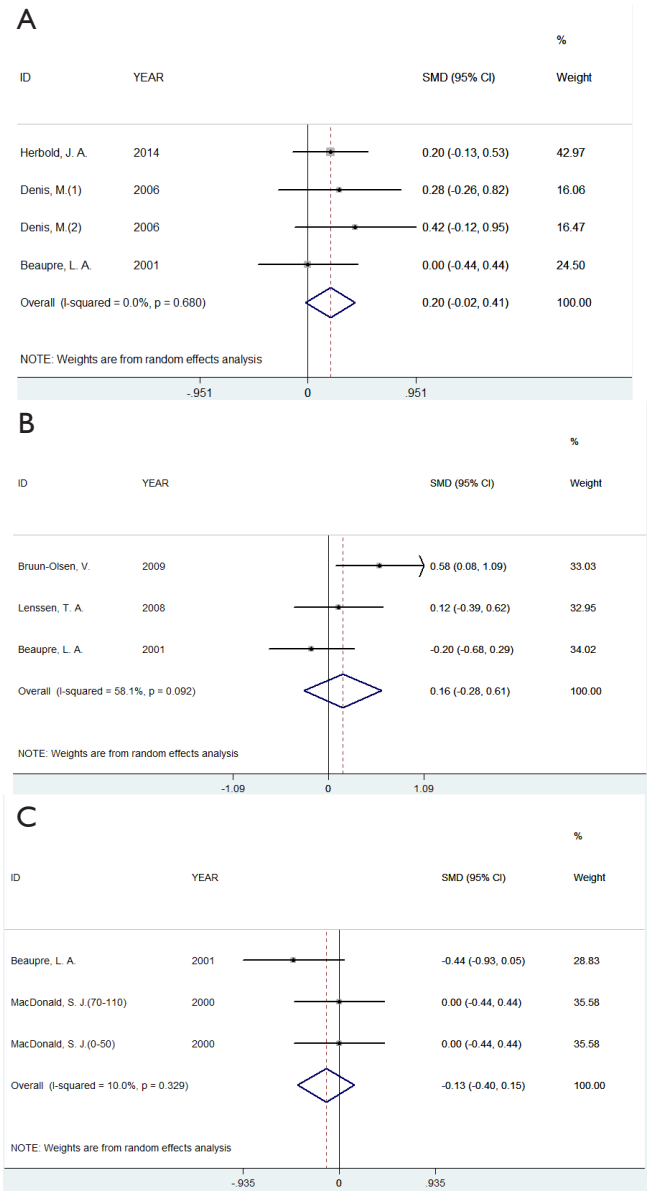

Figure 3 Active knee extension analyses after total knee arthroplasty (TKA) by meta-analysis. (A) Forest plot of ROM at discharge compared between CPM group and non-CPM group; (B) forest plot of ROM at 3 months after discharge compared between CPM group and non-CPM group; (C) forest plot of ROM at more than 6 months after discharge compared between CPM group and non-CPM group.

Some limitations should be discussed in present meta-analysis. Language, publication and the CPM machine were considered the majority biases in this study. First, only literatures published English were included. Second, fewer articles about negative results were published due to researchers, subsidized unit and publishers. Third, the differences of CPM machines used in various studies may contribute to biases in this study. Additionally, significant heterogeneity was detected in analyses of active knee flexion at time of discharge from hospital, 6 weeks and more than 6 months, which caused by different measurements of the control groups. Thus subgroup analyses were conducted between CPM-treated group and normal standard physiotherapy-treated group and the results were the same as the overall analyses.

Conclusions

In present study, a meta-analysis was conducted to determine the association between CPM and ROM after TKA. Through establishing strict inclusion and exclusion criteria, outcomes of active knee flexion ROM and active knee extension ROM between CPM-treated patients and non-CPM treated patients were summarized to obtain more scientific and accurate results. The results showed that CPM had little effects on the recovery after TKA in terms of active knee flexion and active knee extension ROM. Given the limitation of our study, further analyses should be conducted to determine the effects of CPM following TKA by integrating other related indexes.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/aoj.2016.04.02). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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