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Effects of proprioceptive training in the recovery of patients submitted to meniscus surgery: systematic review and meta-analysis

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ABSTRACT

Objective To evaluate the effects of proprioceptive training on rehabilitation of knee after arthroscopic partial meniscectomy (APM).

Design PubMed, EMBASE, The Cochrane Library, Web of Science, China National Knowledge Infrastructure, Technology Periodical Database, WanFang Data and China Biology Medicine were searched until December 2021 for randomised controlled trials.

Participants Patients who have undergone APM for meniscus injury caused by traumatic tear.

Results A total of 9 studies with 453 patients were included in this study for meta-analysis, and 2/9 with high quality, 6/9 with moderate quality. Based on very low quality evidence, the pooled effect showed significant improvement for proprioceptive training group in proprioception test ($p<0.05$, $I^2=18\%$), knee extensor muscle strength ($p<0.05$, $I^2=29\%$), knee flexor muscle strength ($p<0.05$, $I^2=0\%$) and knee function score ($p<0.05$, $I^2=0\%$) compared with conventional training group in patients after APM.

Conclusion Based on very low quality, adding proprioceptive training to conventional rehabilitation programmes might be beneficial to promote functional recovery for patients after APM. It is necessary to carry out more samples and higher quality large-scale studies to provide high evidence in the future.

PROSPERO registration number CRD42020213201.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This meta-analysis was preregistered and conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.
- ⇒ Eight electronic databases were searched to provide a comprehensive range of studies.
- ⇒ Differences in the control interventions, the time-course of treatment, the start time of intervention and assessment may increase heterogeneity and bias.

INTRODUCTION

Meniscal injuries are one of the most common diseases in orthopaedics, with an annual average of 60–70 meniscal injuries per 100 000 cases concerning knee injuries.[1 2] Meniscus tears were detected in up to 80% of cases when people have MRI scans to check the knee.[3] This type of injury is generally classified into two aetiologies.[4–6] One is caused by traumatic or sports injuries when axial loads are transmitted directly to the flexed knee joint with rotation. The other is defined as a degenerative change and often accompanied by degenerative changes in cartilage, mostly found in middle-aged and elderly people, which is often involved in knee osteoarthritis.[1 3] Arthroscopic partial meniscectomy (APM) is among the most common procedures performed for their treatment.[1 7 8] Study shows that about 636 000 knee arthroscopy procedures are performed every year in the USA.[3] In addition, recent studies have shown that surgical treatment has been transferred toward facilitating meniscal repair to maintain meniscal tissue integrity whenever possible, prevent secondary cartilage degeneration and improve knee joint function.[1 9–11] However, postoperative patients experience pain and swelling leading to loss of range of movement, proprioceptive deficits, neuromuscular and biomechanical changes, decreased quadriceps femoris muscle strength, and further leading to dysfunction. The dysfunction especially in proprioception which perceives changes in the state of motion and initiates protection and muscular reflexes to keep dynamic stabilising are prone to increase the risk of degenerative disease or reinjury in the long-term after surgery.[1 12–14]

Proprioception plays an important role in postoperative rehabilitation. The inputs from the sensory organs are processed in the brain and integrated with visual and vestibular information to generate a sense of position and movement through space.

Proprioceptive training can stimulate the sensory organ to send specific signals to control the relevant muscles to maintain stability through specific dynamic movement exercises such as practices of balancing, positioning, gait flexibility, agility and neuromuscular.[15–17] In recent years, adding proprioceptive training to conventional rehabilitation has been widely used in postoperative rehabilitation of joints at different times, some on the first day after surgery, and some 3 months after surgery, which proved to be effective in improving proprioception and activity function.[1] Besides, benefits could be obtained after proprioceptive training for not only patients with anterior cruciate ligament reconstruction,[18 19] knee osteoarthritis,[20] hip and knee replacement,[16 21] but also athletes with the prevention of sports injuries.[22–24]

Proprioception training is beneficial to patients with APM. According to previous trials, some studies have shown that proprioceptive training has a significant improvement on knee rehabilitation for patients with APM.[25 26] However, no significant difference is shown between patients undergoing proprioceptive training and counterparts without such treatment after surgery.[27 28] Considering the differences in the efficacy of proprioceptive training applied in the rehabilitation, this study will not only meta-analyse the effect of proprioceptive training on the recovery of knee proprioception and muscle strength among patients with APM caused by traumatic tear but also provide reliable medical evidence for the efficacy of proprioceptive training on the recovery of proprioception and function after APM.

METHODS

Protocol and registration

This systematic review and meta-analysis was conducted following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

The protocol of the current review was registered on the International Prospective Register of Systematic Reviews (2021).

Patient and public involvement

Patients and/ or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Search strategy

A comprehensive search using the electronic databases of PubMed, EMBASE, Cochrane Library, Web of Science, China National Knowledge Infrastructure, Technology Periodical Database, WangFang Data and China Biology Medicine was conducted in December 2021. Following keywords and their varies were used: proprioceptive training, sensorimotor training, proprioceptive neuromuscular facilitation, neuromuscular training, balance training, meniscectomy. The language was restricted to Chinese and English. Detailed search strategies based on guidance from the Cochrane handbook for all the above databases were shown in online supplemental appendix S1.

Study selection

All records were managed with Endnote X9. The republished articles and no English abstract articles were excluded. Two authors (XL and JM) screened the studies and extracted the data independently according to the inclusion and exclusion criteria. The information of author, publication year, demographics of participants, intervention, the start time of intervention, training time and outcomes were recorded. Any disagreements were resolved by discussion or umpired with a third reviewer (JW).

After we reviewed relevant articles, eligibility criteria for this review based on PICOS frameworks (Population, Intervention, Comparison, Outcome and Study) were as follows: (1) Population: patients who have undergone APM for meniscus injury caused by traumatic tear, whose race, nationality and duration of disease are not limited, patients who have undergone meniscal surgery combined with other procedures such anterior cruciate ligament reconstruction would be excluded; (2) Interventions: proprioceptive training alone or combined training with conventional rehabilitation were seemed as experimental groups; (3) Comparison: conventional rehabilitation training (including ankle pump movement, continuous passive motion, weight-bearing exercise, strength training, etc) were applied to control groups, control groups intervention did not include proprioceptive training; (4) Outcome: at least one of the outcomes of extensor, flexor muscle strength, knee function score or proprioception test was reported; (5) Study: randomised controlled trial (RCT) published in English or Chinese.

Risk of bias assessment

Two investigators independently assessed the quality of the literature using the Physiotherapy Evidence Database (PEDro) scale.[29] Eleven criteria were used in the PEDro scale, and each criterion was rated as 'yes' or 'no'. Each yes would earn one score. However, the first question, 'Whether we should make a detailed sampling criteria for the experiment' is excluded. The full mark is 10. A total PEDro score of ≥7 was considered as high quality, 5–6 as moderate quality and ≤4 as low quality.[29] The scores were given independently by two researchers, and results would be rediscussed with a third researcher in case of disagreement.

Data extraction

Two researchers independently selected the literature and extracted the data according to sampling criteria. The selection of the literature was based on the relevance of the research topic. Irrelevant studies would be excluded by reading the title and abstract of the literature. Final decision would be made through a detailed reading of the full text. Data extraction was performed independently by two researchers, including: first author, year, age, sample size, type, time and frequency of intervention, and outcome indicators. Disagreements would be resolved through discussions.

Statistical analysis

Data included in the study were analysed using Review Manager 5.3. Mean difference (MD) was used for consistent measuring units. Standardised mean difference (SMD) was used for inconsistent measuring units to calculate the effect size and its 95% CI for each combination.[30] The heterogeneity of treatment effects was examined by calculating the I^2 index. Interpretation of I^2 is as follows: 0%–40%: might not be important; 30%–60%: may represent moderate heterogeneity; 50%–90%: may represent substantial heterogeneity; 75%–100%: considerable heterogeneity. When I^2 was less than 50%, the combined effect was considered as mild heterogeneity and a fixed-effect model was used for meta-analysis; when I^2 was greater than 50%, the heterogeneity was considered to be high. Therefore, a random-effect model was used for meta-analysis, and sensitivity analysis was performed to identify the source of heterogeneity. The absence of blinding and differences in the control interventions, the time-course of treatment, the start time of intervention and assessment may increase heterogeneity. P value level of 0.05 was set for between-group differences.

Grading of Recommendations, Assessment, Development and Evaluations assessment

The GRADE approach (Grading of Recommendations, Assessment, Development and Evaluations) was used to appraise and summarise the body of evidence.[31] GRADE is an internationally approved standard for managing complex evidence reviews. For results based only on RCTs, certainty was initially considered as high. Thereafter, certainty could be rated down based on factors such as the risk of bias, imprecision, inconsistency, indirectness, and potential publication bias.[31 32]

RESULTS

Study characteristics

As of December 2021, 155 potentially relevant studies were retrieved according to the sampling criteria, and 9 relevant articles were selected, 6 in Chinese[26–28 33–35] and 3 in English,[27 36 37] with a total of 453 patients. A detailed selection process is shown in figure 1.

All included literature entailed RCTs concerning the effect of proprioceptive training on knee function among patients with APM.[25–28 33–37] Seven studies reported that the patients combined with Anterior Cruciate Ligament (ACL) injuries were excluded,[25 27 33–37] but the others[26 28] did not report in the methods. There are also various methods for assessing knee flexor and extensor muscle strength,[38 39] such as isokinetic strength,[27 36] isometric strength,[28 33] peak torque strength[37] and relative torque strength.[26] There are also various methods for assessing knee function scores such as Lysholm scores[25 34–36] and Knee Injury and Osteoarthritis Outcome Score (KOOS).[27] Specific study characteristics are shown in table 1.

Quality assessment

The quality of the included studies was evaluated according to the PEDro quality assessment scale, most of all had methodological flaws in the subject, therapist and assessor blinding. Two studies obtained high quality,[27 37] six studies obtained moderate quality[25 26 33–36] and one study obtained low quality,[28] as detailed in table 2.

Effects of proprioceptive training

Proprioceptive test

Three studies,[25 28 33] assessing 141 participants, performed knee proprioceptive test. All three studies assessed positioning sense using the threshold to detection of passive motion, and MD was applied in the process of data merging. Pooling of the data using a random effects model (I^2=92%, figure 2A) showed a statistical significance compared with control group (MD=−1.73, 95% CI −2.98 to −0.48, p<0.001), which could prove the positive effects brought by proprioceptive training for patients' knee proprioception. After sensitivity analysis, the study[28] was identified as a source of high heterogeneity, which decreased significantly (p<0.00001, I^2=18%, figure 2B) after being excluded. It was considered as a result of the small sample size and improper methodology used in the study.

Flexor muscle strength

Five studies,[26 27 33 36 37] assessing 234 participants, performed the knee flexor muscle strength test. Pooling of the data using a random effects model (I^2=76%, figure 3A) showed no statistical significance compared with control group (SMD=0.56, 95% CI 0.01 to 1.11, p=0.05). After sensitivity analysis, the study[33] was identified as the source of high heterogeneity, which decreased significantly (I^2=0%, p=0.04, figure 3B) after being excluded, which could justify the positive effects on knee flexor (hamstring) muscle strength brought by proprioceptive training. It was considered as a result of the seniority of the included patients and improper methodology in the study.

Extensor muscle strength

Six studies,[26–28 33 36 37] assessing 259 participants, performed the knee extensor muscle strength test. Pooling of the data using a fixed effects model (I^2=29%, figure 4) showed a statistical significance compared with control group (SMD=0.31, 95% CI 0.06 to 0.56, p=0.01), which could justify that proprioceptive training could improve knee extensor (quadriceps) muscle strength.

Function scores

Five studies, assessing 286 participants, performed the knee function scores assessed by Lysholm score[27] and KOOS.[25 34–36] Pooling of the data using a random effects model (I^2=93%, figure 5A) showed no significant difference between the two groups (SMD=0.85, 95% CI −0.13 to 1.84, p=0.09). After sensitivity analysis, two studies[27 36]

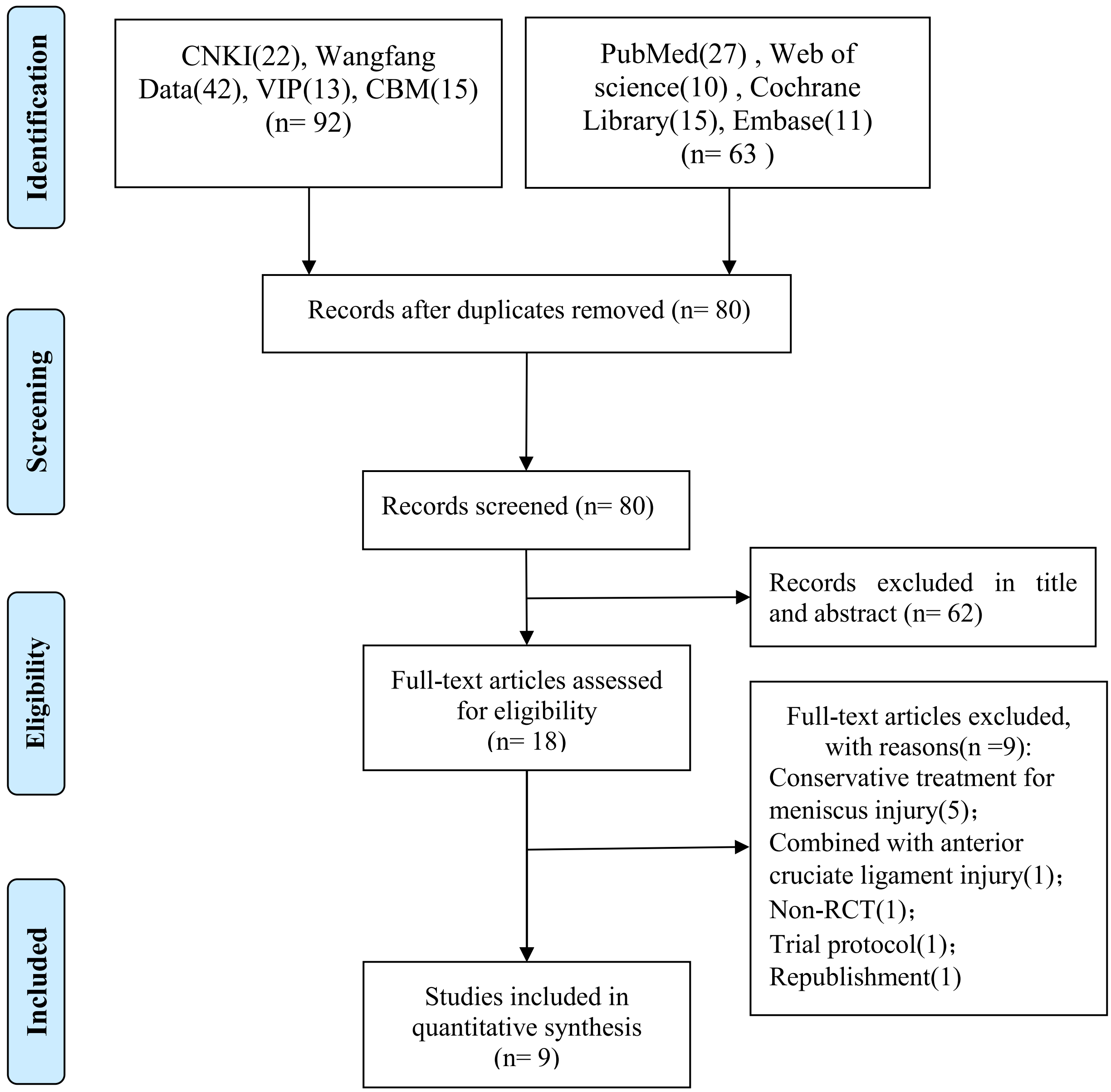

Figure 1 Flow chart of literature selection. From Moher *et al*.[47] CBM, China Biology Medicine; CNKI, China National Knowledge Infrastructure; RCT, randomised controlled trial; VIP, Technology Periodical Database.

were found to be the source of high heterogeneity, which decreased significantly (I^2=0%, p<0.00001, figure 5B) after being excluded one by one. It was considered partly because of the blank control as the control group.

GRADE approach level of evidence

Pooled results of the proprioceptive test, knee flexor muscle strength, knee extensor muscle strength, knee function scores comparing proprioceptive training group to conventional training group were considered of very low quality. See details of the GRADE approach and conclusions in table 3.

DISCUSSION

This study is the first systematic review and meta-analysis to evaluate the functional effects of proprioceptive training after APM. Nine RCTs with 453 patients containing 2 high-quality studies, 6 moderate-quality studies and 1 low-quality study, respectively were included. According to the results of meta-analysis, the included studies showed that the proprioceptive training could significantly improve knee proprioception, flexion and extension muscle strength in patients after APM, while the positive effects on knee function scores were not significant. GRADE approach showed that all the pooled results comparing

Table 1 Characteristics of included studies

Author (Year)	Age(T/C)	Sample size (T/C)	Intervention (T/C)	Intervention time from surgery	Frequency	Duration	Outcomes
Li *et al*[28]	32.0±6.25 26.5±6.75	12/13	CT+PT/CT	First day	2 times per day, 5–7 times per week	8 weeks	Position sense; Isometric strength
Xiong *et al*[26]	29.2±5.12 28.3±5.36	15/15	CT+PT/CT	First day	No description	8 weeks	Isometric strength
Huang *et al*[25]	18–40	30/30	CT+BT/CT	First day	No description	12 weeks	Lysholm; Position sense
Ouyang *et al*[33]	49.20±7.54 48.50±9.93	28/28	CT+PT/CT	6 hours	1 times per day, 30 min for each	12 weeks	Position sense; Isometric strength
Yu *et al*[34]	42.22±4.35 42.69±5.08	43/43	CT+PT/CT	First day	2 times per day, 5–7 times per week	8 weeks	Lysholm
Jiang and Chu[35]	40.85±5.47 40.53±5.46	24/24	CT+PT/CT	First day	1 times per day, 6 times per week	8 weeks	Lysholm
Zhang *et al*[36]	23.16±3.45 23.25±3.52	15/15	NT/CT	First day	30 min for each, 3 times per week	8 weeks	Lysholm; Isokinetic strength
Ericsson *et al*[37]	45.4±3.2 45.9±3.2	28/28	NT/Blank control	12 months	5 times per week	8 weeks	Isokinetic strength
Hall *et al*[27]	42.8±5.4 43.2±5.6	31/31	NT/Blank control	3 months	30–45 min for each, 1–3 times per week	12 weeks	KOOS; Isokinetic strength

BT, balance training; CT, conventional training; KOOS, Knee Injury and Osteoarthritis Outcome Score; NT, neuromuscular training; PT, proprioceptive training.

the proprioceptive training group to the conventional training group were considered of very low quality.

Proprioceptive training could significantly improve knee proprioception in patients after APM. The previous study[40] showed that patients with isolated meniscal tears had a significant proprioceptive deficit when compared with their uninjured contra-lateral knee and the healthy subjects. Located in the outer third place of the meniscus, the proprioceptors could sense the condition of movement from the knee joints and their surrounding muscles, playing an important role in the maintenance of knee stability by regulating the amount of knee muscle strength through proprioceptive feedback.[15 25 28] Proprioception refers to the signal of body changes generated by proprioceptors in static or dynamic motion to specific parts of the body, which generally include the sense of static position, dynamic motion velocity, the direction of acceleration and the perception of joint pressure.[41] Proprioceptive feedback mechanism is a subjective perception of knee stability.[42] Once the knee proprioception is stimulated, signals are sent to the central nervous system, including the spinal cord, brainstem and cerebral cortex, where they are analysed and transmitted downward to protect the knee from injury by stimulating or

Table 2 Evaluation of the quality of the included documents through PEDro

Study	1	2	3	4	5	6	7	8	9	10	11	Total score	Level
Li *et al*[28]	×	×	×	×	×	×	×	√	√	√	√	4	Low
Xiong *et al*[26]	√	√	×	√	×	×	×	√	√	√	√	6	Fair
Hung *et al*[25]	√	√	×	√	×	×	×	√	√	√	√	6	Fair
Ouyang *et al*[33]	√	√	×	√	×	×	×	√	√	√	√	6	Fair
Yu *et al*[34]	√	√	×	√	×	×	×	√	√	√	√	6	Fair
Jiang and Chu[35]	√	√	×	√	×	×	×	√	√	√	√	6	Fair
Zhang *et al*[36]	√	√	×	√	×	×	×	√	√	√	√	6	Fair
Ericsson *et al*[37]	√	√	√	√	×	×	√	√	√	√	√	8	High
Hall *et al*[27]	√	√	√	√	×	×	√	√	√	√	√	8	High

1=inclusion exclusion criteria; 2=randomised group; 3=allocation concealment; 4=similar baseline; 5=subject blinding; 6=therapist blinding; 7=assessor blinding; 8=more than 85% of patient measures; 9=intention to treat; 10=between-group analysis; 11=at least one point measure. √: yes, no risk; ×: no, risky.

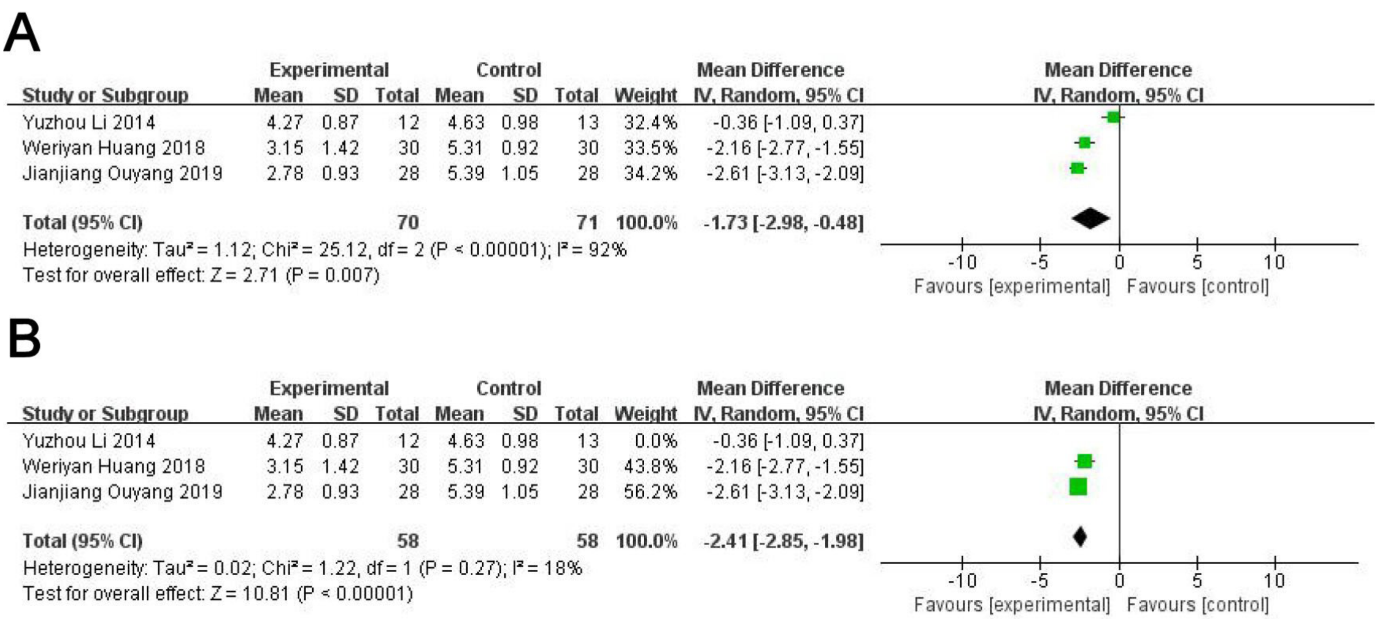

Figure 2 Meta-analysis of proprioceptive tests. (A) All studies; (B) after sensitivity analysis.

inhibiting the corresponding muscles, adjusting posture and balancing in time.[19 43] After the meniscus injury partially or completely, the proprioception and neuromuscular control ability of the knee are significantly decreased.[28 43] Partial meniscus impairment could also be found after APM. APM could not result in a significant improvement in proprioceptive function.[44] Impaired proprioceptive feedback mechanism would predispose to reflex joint instability and irregular postural reflexes, leading to an increasing risk of degenerative disease or reinjury.[19 36 45] Postoperative proprioceptive training could effectively restore the proprioceptive function, which is consistent with our results.

The results in this study show significant improvement for the proprioceptive training group in knee extensor muscle strength, but no differences in knee flexor muscle strength and function score compared with the conventional training group. Although the p value in improving flexor muscle strength is 0.05, the result is still valuable when the study that causes high heterogeneity is excluded, but further research is needed to confirm it. Conventional rehabilitation programmes mainly employ

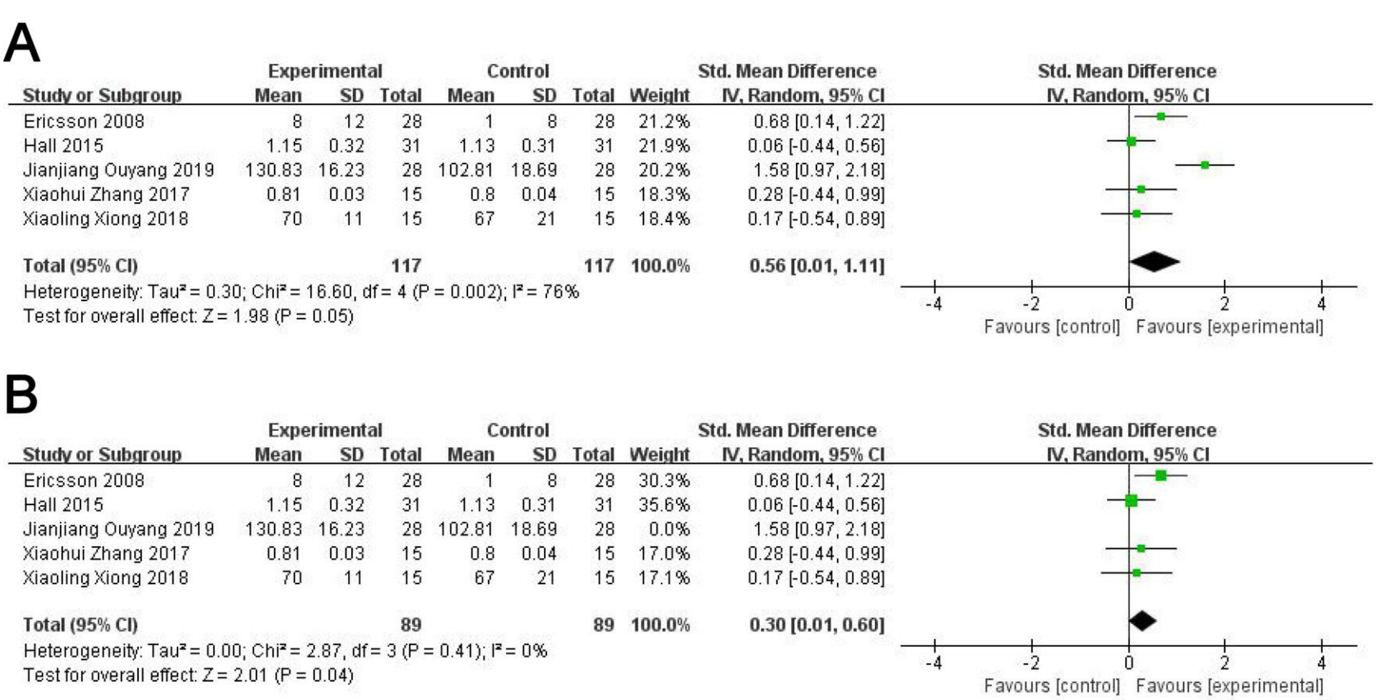

Figure 3 Meta-analysis of knee flexor muscle strength. (A) All studies; (B) after sensitivity analysis.

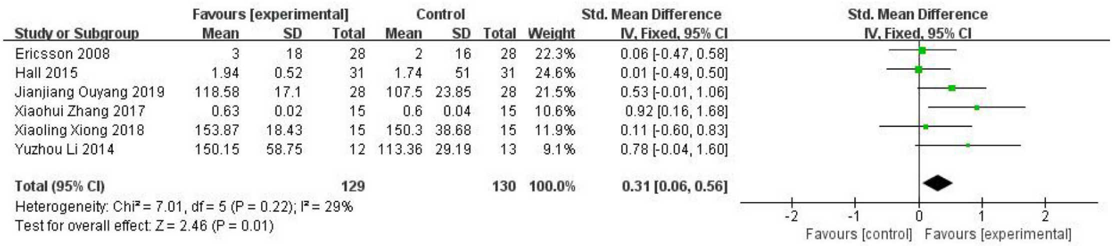

Figure 4 Meta-analysis of knee extensor muscle strength.

isometric and isotonic exercises to improve muscle strength, while proprioceptive training programmes include balance enhanced training, plyometric stretch-contraction cycles, knee dynamic stability, proprioception and agility exercises.[36] Progressive training of proprioceptive training programmes can stimulate stretch-contraction and enhance the improvement in muscle strength, which may explain the greater muscle strength observed in the proprioceptive training group.[36 37] In addition, failure to improve knee function significantly in this study might be explained by the poor transfer of the trained skills to gait. No exercises in the control group resemble the heel-toe action of gait, and this degree of task specificity may be required to modify gait. Moreover, the setting of a blank control group and lack of assessment of compliance for two groups may further explain the less functional improvement observed in the proprioceptive training group.[27 36]

In the clinic, proprioceptive training is often added into conventional rehabilitation programmes to improve the proprioception, muscle strength and function of patients after APM. Although the results of this study show no significant improvement for the proprioceptive training group in function score, proprioceptive training is still recommended in most studies to rehabilitation programmes.[1 25–28 36] The findings obtained by this review reinforce what is found in other conditions (knee replacement, ACL reconstruction), suggesting proprioceptive to induce functional benefits.

This study also has some shortcomings. First, as seen in figure 2 and table 3, most of the included studies in this study had methodological flaws and a small sample size, mostly the lack of participant, therapist and assessor blinding. These factors might overestimate the efficacy of proprioceptive training.[46] More high-quality studies with a larger sample should be implemented to confirm the efficacy of proprioceptive training. Second, the start time of intervention and assessment in the included studies was inconsistent. The study showed that the incidence of knee osteoarthritis was approximately 50% within 10–20 years from APM.[14] This factor might affect the recovery of knee function and proprioception. In addition, this study generally focused on the effects of proprioceptive training after training and thus lacked studies assessing mid and long-term efficacy. The impact of follow-up time on the efficacy of proprioceptive training needs to

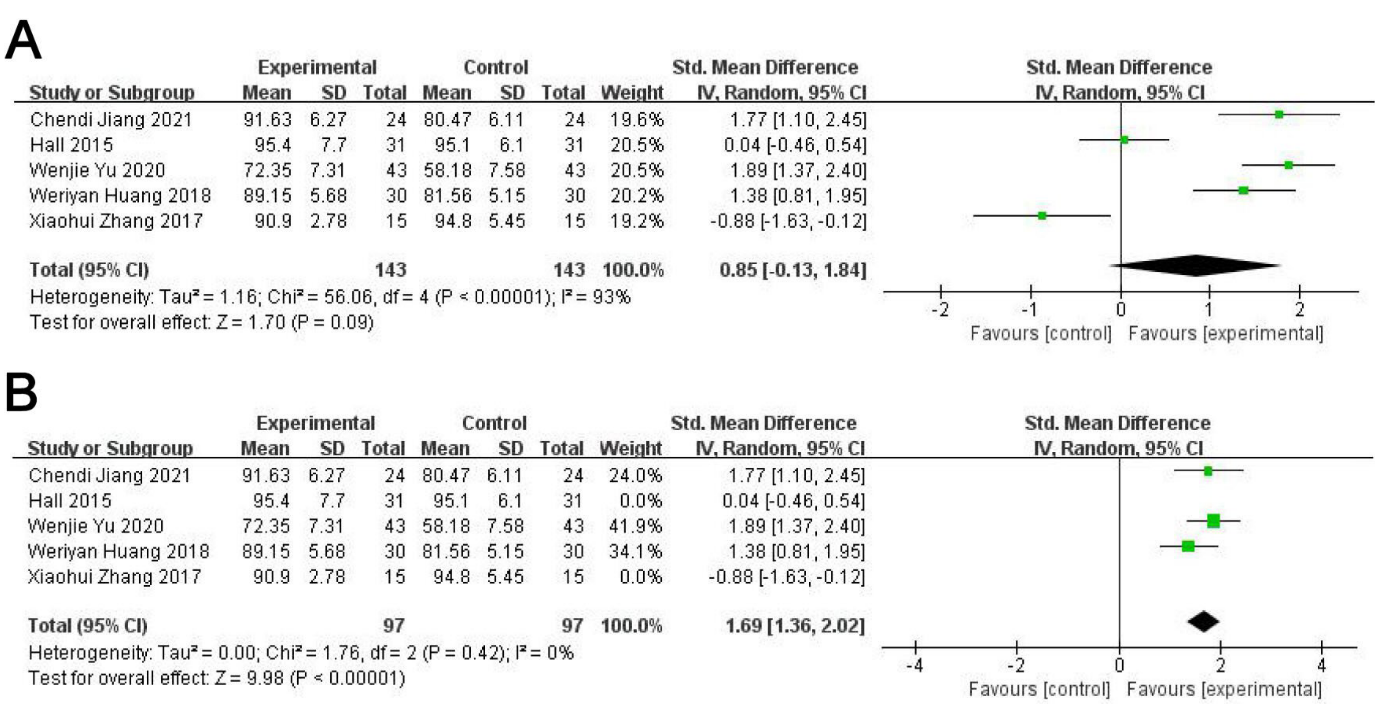

Figure 5 Meta-analysis of knee function scores. (A) All studies; (B) after sensitivity analysis.

Table 3 GRADE evidence profile

Quality assessment							Number of patients		Effect			
Number of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**PT**	**CT**	**Relative (95% CI)**	**Absolute (95% CI)**	**Quality**	**Importance**
Proprioceptive test												
3	RCT	Very serious*	Very serious†	Not serious	Serious§	None	70	71	Risk ratio −1.73 (−2.89 to −0.48)	–	⊕OOO Very low	Critical
Knee flexor muscle strength												
5	RCT	Very serious*	Serious†	Serious‡	Serious§	None	117	117	Risk ratio 0.56 (0.01 to 1.11)	–	⊕OOO Very low	Critical
Knee extensor muscle strength												
6	RCT	Very serious*	Not serious	Serious‡	Serious§	None	129	130	Risk ratio 0.31 (0.06 to 0.56)	–	⊕OOO Very low	Critical
Knee function scores												
5	RCT	Very serious*	Serious†	Serious‡	Serious§¶	None	143	143	Risk ratio 0.85 (−0.13 to 1.84)	–	⊕OOO Very low	Critical

*We downgraded for a quite large risk of bias, due to lack of randomisation, blinding, allocation concealment.
†We downgraded for the high I^2 and reversed the results of functional score.
‡We downgraded for the inconsistence of intervention in the control group.
§We downgraded for less than 400 participants.
¶We downgraded for no significant benefit.
CT, conventional training; GRADE, Grading of Recommendations Assessment, Development and Evaluation; PT, proprioceptive training; RCT, randomised controlled trial.

be explored further. Third, few studies were searched according to the inclusion criteria, and different outcomes were also used. Therefore, the conclusions were not supported by sufficient data. More studies are needed to verify the conclusions of this study. Fourth, as seen in table 1 and figure 5, two studies[27 37] had blank control groups that were different from those in other studies, which could explain the heterogeneity observed in some outcomes. Due to the small number of studies, further subgroup analysis is not applicable. Future studies should standardise interventions in the control group. Fifth, the two studies[26 28] did not explicitly report that patients combined with ACL injuries were excluded, which may lead to potential heterogeneity. None of the original included studies reported whether the included patients had been diagnosed with a traumatic or degenerative meniscal tear before APM. Future studies should develop strict inclusion and exclusion criteria. Finally, a lack of standardised exercise prescription needed to be noted, such as dose, time, intensity and type of exercises, which would be the reason for high heterogeneity. Future studies should provide a standard and clear exercise prescription, which could help develop treatment and evaluation methods.

CONCLUSIONS

Based on very low quality, adding proprioceptive training to conventional rehabilitation training may induce benefits for knee flexor-extensor strength and proprioception in patients after APM. Given the limited number of included studies, a multicentre RCT based on a large sample and a scientific methodology is still needed to further discuss the effects of proprioceptive training on functional recovery in patients after APM.

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Patient consent for publication Not applicable.

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