The Effect of Proprioceptive Neuromuscular Facilitation on Joint Position Sense: A Systematic Review

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Context: Accurate joint position sense (JPS) is necessary for effective motor learning and high performance in activities that require fine motor control. Proprioceptive neuromuscular facilitation (PNF) can be a promising intervention. **Objective:** To examine existing peer-reviewed original studies that have investigated the effect of PNF techniques on the JPS in terms of the methodological quality, PNF techniques, outcomes, and participant characteristics. **Evidence Acquisition:** A systematic literature search was performed using PubMed, EMBASE, MEDLINE, CINAHL, SocINDEX, Scopus, and Cochrane Library from inception to January 2018. The following inclusion criteria were used: (1) assessment of the JPS; (2) peer-reviewed original studies with a randomized controlled trial or quasi-randomized controlled trial design; (3) participants with musculoskeletal disorders or healthy individuals (ie, neither animal studies nor those involving neurological problems); and (4) no cointervention with PNF, except for warm-up procedures. The methodological quality was assessed using PEDro scale and 5 additional criteria. Effect size (η^2) was calculated where a positive value indicated an increased JPS after PNF as compared with other approaches including the wait-and-see method. **Evidence Synthesis:** Nine studies were examined for their methodological quality, and only one study scored >6 on the PEDro scale. Positive and large effect size ($\eta^2 > .14$) was detected in 2 studies where JPS of the knee with contract-relax and replication techniques was assessed in healthy individuals. However, the methodological quality of these studies was poor (PEDro scores of 3 and ≤ 5 in the total quality score out of 16, respectively). **Conclusions:** The current study did not find multiple studies with high methodological quality and similar PNF techniques, outcomes, and characteristics of participants. More high-quality studies are required to achieve a comprehensive understanding of the effect of PNF on the JPS.

Keywords: proprioception, proprioceptive neuromuscular facilitation (PNF) stretching, physical therapy techniques

Proprioceptive deficits including impaired joint position sense (JPS) are considered to be contributing to impaired neuromuscular control, resulting in functional instability and repetitive injury.¹ Furthermore, impaired JPS is associated with impaired muscle performance,² and this combination is associated with functional deficits in people with musculoskeletal disorders.³ Therefore, it is important to identify effective interventions to enhance the JPS for preventing injuries and restoring functions in sports rehabilitation and musculoskeletal physiotherapy. Furthermore, sports performance can be associated with the magnitude of the JPS.⁴ Therefore, interventions to enhance the JPS would be concerns in the area of athletic training and sports science. Proprioceptive neuromuscular facilitation (PNF) can be a promising intervention, and several studies have investigated this subject in the past 15 years.⁵⁻⁷

PNF is an applied technique designed to promote the response of the neuromuscular mechanisms, such as mobility, muscular strength and endurance, joint stability, balance, and neuromuscular control,⁸ by stimulating the proprioceptors within the skin, joints, muscles, and tendons. There are several PNF techniques commonly mentioned in the literature, including the contract-relax method and the contract-relax-antagonist-contract method to improve mobility,⁹ as well as the repeated contraction method and the replication method to facilitate neuromuscular outputs. Several systematic reviews have discussed the effect of the contract-relax and

contract-relax-antagonist-contract methods on the performance in power dominant tasks and endurance dominant tasks.^{10,11} Generally, the 2 methods tend to reduce performance in the power dominant tasks and endurance dominant tasks. However, to our knowledge, thus far, no systematic review has investigated the effect of PNF on the performance of JPS. Studies found that PNF enhanced activities of the superior parietal cortex¹² and cerebellum,¹³ both of which contribute to the JPS.

It may be possible that PNF contributes to enhancement of the JPS, but the effect of PNF on the JPS is hypothesized to differ with different techniques, body regions, and physical problems. A meta-analysis involving several high-quality studies that involve similar techniques, outcome measures, and patient characteristics is required to comprehensively understand the effect of an intervention; however, it is unclear as to how many such studies are available. The present study aimed to examine existing peer-reviewed original studies that have investigated the effect of PNF techniques on the JPS in terms of the methodological quality, PNF techniques, outcomes, and participant characteristics. The findings of this study provide direction for future researches aimed at achieving a comprehensive understanding of the effect of PNF techniques on the JPS.

Methods

Design

This systematic review was undertaken in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines¹⁴ and updated method guidelines for Cochrane Musculoskeletal Group systematic reviews and meta-

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analyses.¹⁵ This study was registered in the international prospective register of systematic reviews (CRD42016041823).

Identification and Selection of Studies

A systematic search was performed using the refined key search terms (Appendix 1) on PubMed, EMBASE, MEDLINE, CINAHL, SocINDEX, Scopus, and the Cochrane Library from inception to January 2018. Cross-referencing was undertaken using the relevant reviews.

The following inclusion criteria were used: (1) assessment of the JPS; (2) peer-reviewed original studies with a randomized controlled trial or quasi-randomized controlled trial design; (3) participants with musculoskeletal disorders or healthy individuals (ie, neither animal studies nor those involving neurological problems); and (4) no cointervention with PNF, except for warm-up procedures. There was no language limitation. One author (H.T.) undertook database search. Screening of the title, abstract, and full text was performed by 2 authors (S.O. and Y.O.) independently. Full-text inspection was undertaken for the studies that either of the authors retained for full-text inspection during the screening process. There was no disagreement regarding the inclusion of the studies as per the inclusion criteria.

Assessment of Methodological Quality

We used the PEDro scale.^{16–18} In the PEDro scale, a high-quality study is defined as a study with a PEDro score ≥ 6 .¹⁷ Reducing the cutoff score from 6 to 5 did not affect the overall outcome, and a cutoff score of 5 was used in some reviews.^{19–21} Therefore, we investigated if the number of high-quality studies changed using the 2 thresholds.

To further understand the methodological quality, the following 5 points were also assessed (Appendix 2): (1) approval from the ethics committee and informed consent (criterion A), (2) trial registration (criterion B), (3) inclusion of an adequate sample size (criterion C), (4) reliability of the outcome measures (criterion D), and (5) appropriate statistical assessment with effect size calculation (repeated-measures analysis of variance with effect size calculation for parametric analysis and Mann–Whitney *U* test using predifference to postdifference with effect size calculation; criterion E). These criteria have been used in other critical appraisal tools and CONSORT statement.^{22,23}

The International Committee of Medical Journal Editors requested that all clinical trials be registered in the database before patient recruitment in 2005. Therefore, we evaluated if trial registration was undertaken for studies published after 2005.

The 2 authors (S.O. and Y.O.) assessed the methodological quality, and any disagreement between them was resolved by another author (H.T.). Agreement regarding the PEDro scale and the additional criteria between the 2 authors (S.O. and Y.O.) was examined with Cohen kappa and percentage agreement, where the following interpretations of the kappa value were used: $<.4$ = poor agreement, $.41$ to $.60$ = moderate agreement, $.61$ to $.80$ = good agreement, and $.81$ to 1.0 = very good agreement.²⁴ All the authors were certified in the PEDro scale training program.

Data Analyses

Data were extracted by the 2 authors (S.O. and H.T.) independently. Any disagreement was resolved by another author (Y.O.).

Effect size (η^2) was calculated, where η^2 values of $<.003$, $.01$ to $.039$, $.06$ to $.11$ and $>.14$ represent no effect, small effect,

intermediate effect, and large effect size, respectively.²⁵ A positive value in the effect size indicated increased JPS after PNF compared with that with other approaches (control groups), including the wait-and-see method. Data of the control group were extracted from the wait-and-see method when it was reported; otherwise, data of the control groups were extracted from other approaches compared with the PNF group. A negative effect size value indicated decreased JPS after PNF compared with that with the control groups. Effect size (η^2) for the interaction effect and intervention effect was calculated. When the effect size (η^2) for the interaction effect and/or the intervention effect was not reported, the η^2 value between the PNF group and the control group was calculated using the within-group change scores. Furthermore, when the within-group change scores were not reported and when the baseline scores were assumed to be comparable, the η^2 value between the PNF group and the control group was calculated using the postintervention scores.¹⁹ The corresponding author of the literature was contacted twice via e-mail within a 1-month interval in case of insufficient information for data extraction.

Results

Study Selection

Figure 1 presents the flow of study selection. Nine studies were assessed for the methodological quality. Lazarou et al⁵ provided us with unpublished data of effect sizes.

Characteristics of the Studies

Table 1 summarizes the 9 studies. Two studies were published in Japanese, while the others were in English.

Table 2 presents the PEDro scores and additional criteria A to E. For the PEDro scale, the reviewers scored 99 items and agreed on 96 items (97.0% agreement). The kappa value with 95% confidence intervals was $.94$ ($.87$ – 1.00) ($P < .001$), and the overall interreviewer agreement of the methodological quality was good. With respect to the additional criteria A to E scale, the reviewers scored 45 items and agreed on all the items (100% agreement). The kappa value with 95% confidence intervals was 1.0 (1.0) ($P < .001$), and the overall interreviewer agreement of the methodological quality was good. More than 80% of studies failed to fulfill criterion 3 (concealed allocation), criterion 5 (subject blinding), criterion 6 (therapist blinding), criterion 9 (intention-to-treat analysis), criterion B (trial registration), criterion C (inclusion of an adequate sample size), and criterion E (appropriate statistical assessment with effect size calculation). Regardless of the PEDro cutoff score (5 or 6), 6 out of 9 studies were not considered to be of high quality. Furthermore, none of the studies satisfied all the additional criteria (criteria A–E). All the studies except the one by Padua et al⁷ were published after 2005; however, only one study⁵ registered the trial.

Discussion

The current study systematically reviewed the studies that investigated the effect of PNF techniques on the JPS in terms of methodological quality, PNF techniques, outcomes, and participant characteristics. This current review provides us suggestions for enhancing the methodological quality by understanding the common errors in existing studies and gaps in the literature.

Figure 1 — Flow of the study selection. JPS indicates joint position sense; RCT, randomized controlled trial.

Regardless of the PEDro cutoff score, 6 out of 9 studies were not considered to be of high quality. Furthermore, none of the studies satisfied all the additional criteria. Even in the study by Lazarou et al,⁵ wherein the methodological quality was considered high as per the PEDro score, additional criteria C (inclusion of an adequate sample size) and D (reliability of the outcome measures) were not satisfied. These faults in the additional criteria can influence conclusions of the study⁵; thus, the results should be cautiously interpreted. No study satisfied criterion C (inclusion of an adequate sample size) and criterion E (appropriate statistical assessment with effect size calculation). Underpowered results and inappropriate statistical assessment or the lack of effect size calculation influenced the study conclusions. Furthermore, it was found that most studies in the current review did not register the trial and did not follow global publication standards. Therefore, we recommend that we should assume the lack of convincing information about the effect of PNF on the JPS. In order to fully

understand the effect of PNF on the JPS, further well-designed studies are required.

Considerations for Future Studies

We calculated the effect sizes for the effect of PNF on the JPS in each study. A large effect size was observed in 2 studies^{6,31} although the methodological quality was poor in each study. These studies suggest promising conditions that can be used in future trials. First, regarding a target joint, the 2 studies with a large effect size^{6,31} used the knee. Thus, the knee can be a promising target in future trials.

Regarding the PNF technique, Cho et al⁶ used contract-relax and Ito et al³¹ used replication. Only the postintervention scores were available from the Cho et al's study⁶; thus, effect size was calculated using the postintervention scores. In the study by Ito et al,³¹ only within-group changes in the scores were available;

Table 1 Summary of the 9 Studies Analyzed in This Review

Study/ corresponding author responded or not (including not contactable)	Design	Participants	Interventions relevant to this review	Measures	Effect size of intervention in comparison with a control condition (methods of effect size calculation)
Lazarou et al ⁵ Responded	RCT	n = 20 • PNF (n = 10) • Control (n = 10) Eligibility • Ankle sprain • No participation in any form of supervised training after the injury • Exclusion criteria: chronic ankle instability, grade 3 ankle sprain, medial or interosseous ligament ankle sprain, concurrent fracture, history of nerve injury or ankle surgery to lower limbs, and further ankle injury after the sprain Age • PNF: mean (SD) = 22 (4) y • Control: mean (SD) = 22 (2) y Gender • PNF: 7 women and 3 men • Control: 7 women and 3 men	Body part: ankle PNF • RC using rhythmic stabilization first for the diagonal ankle movements without movements of the hip and knee (10-s isometric contraction of agonistic and antagonistic muscles, 2-min resting, and combination of resisted active concentric contraction for 5 s, resisted isometric contraction for 5 s, and resisted eccentric contraction for 5 s of agonistic muscles, with no rest between contractions) • 5–15 repetitions/set with 30-s rest between sets • 20 min of PNF training/session with a total training time of 50–60 min/session • 10 sessions for 6 wk Control • Balance training for 50–60 min/session (wobble board, firm surface, and soft-surface activities with eyes open) • 10 sessions for 6 wk	Outcome measures relevant to this review • Active repositioning acuity • Target position: 10° of dorsiflexion, 15° of plantar flexion, 30° of plantar flexion • Storage time: 15 s • Follow-up: 6-wk postintervention (follow-up 1) and 8 wk after the follow-up 1 (follow-up 2) Measurement side: injured side Measurement posture: sitting Measurement method: • Absolute error • Biodex System II Pro isotonic dynamometer (Loredan Biomedical, Inc, Sacramento, Calif) • Internal goniometer of the Biodex Repetitions for the measure: 3	$\eta^2 = .0025$ (between-group difference in prechange to postchange scores, follow-up 1, 10° of dorsiflexion) $\eta^2 = .0004$ (between-group difference in prechange to postchange scores, follow-up 1, 15° of plantar flexion) $\eta^2 = .0529$ (between-group difference in prechange to postchange scores, follow-up 1, 30° of plantar flexion) $\eta^2 = .1156$ (between-group difference in prechange to postchange scores, follow-up 2, 10° of dorsiflexion) $\eta^2 = .0081$ (between-group difference in prechange to postchange scores, follow-up 2, 15° of plantar flexion) $\eta^2 = .0016$ (between-group difference in prechange to postchange scores, follow-up 2, 30° of plantar flexion)
Bjorklund et al ²⁶ Not responded	RCT (cross-over with washout period of a minimum of 2 d [mean 7.2 d])	n = 18 • PNF (n = 18) • Control (n = 18) Eligibility • Healthy individuals (no current musculoskeletal problem in the right shoulder) • Dominant side of right Age • Men: mean (SD) = 24 (3) y • Women: mean (SD) = 21 (2) y Gender: 9 men and 9 women	Body part: shoulder PNF 1 • CR stretching for shoulder horizontal abduction (isometric contraction in the direction of the horizontal adduction for 5 s, 2- to 3-s resting, and then static stretching in the direction of horizontal abduction for 20 s × 3 sets) PNF 2 • CR stretching for shoulder horizontal adduction (isometric contraction in the direction of the horizontal abduction for 5 s, 2- to 3-s resting, and then static stretching in the direction of horizontal adduction for 20 s × 3 sets) Control • 5-min resting in sitting	Outcome measures relevant to this review • Active repositioning acuity • Target position: 15° and 30° horizontal angle between the arm and a sagittal plane • Storage time: 5 s Measurement side: right side Measurement posture: sitting Measurement method: • Variable error • Absolute error • Electromagnetic tracking system Repetitions for the measure: 6	$\eta^2 = -.030$ (between-group difference in prechange to postchange scores, variable error, PNF 1 vs Control, 15° horizontal angle between the arms) $\eta^2 = -.011$ (between-group difference in prechange to postchange scores, variable error, PNF 1 vs Control, 30° horizontal angle between the arms) $\eta^2 = -.059$ (between-group difference in prechange to postchange scores, variable error, PNF 2 vs Control, 15° horizontal angle between the arms) $\eta^2 = .018$ (between-group difference in prechange to postchange scores, variable error, PNF 2 vs Control, 30° horizontal angle between the arms) $\eta^2 = -.009$ (between-group difference in prechange to postchange scores, absolute error, PNF 1 vs Control, 15° horizontal angle between the arms) $\eta^2 = .007$ (between-group difference in prechange to postchange scores, absolute error, PNF 1 vs Control, 30° horizontal angle between the arms) $\eta^2 = -.009$ (between-group difference in prechange to postchange scores, absolute error, PNF 2 vs Control, 15° horizontal angle between the arms) $\eta^2 = -.011$ (between-group difference in prechange to postchange scores, absolute error, PNF 2 vs Control, 30° horizontal angle between the arms)

(continued)

Table 1 (continued)

Study/ corresponding author responded or not (including not contactable)	Design	Participants	Interventions relevant to this review	Measures	Effect size of intervention in comparison with a control condition (methods of effect size calculation)
Padua et al ⁷ Not responded	RCT	n = 57 • PNF (n = 13) • Control (n = 15) • Open kinetic chain exercise (n = 13) • Close kinetic chain exercise (n = 13) Eligibility • Healthy individuals • No history of injury to the upper-extremity within the preceding 12 mo • No history of glenohumeral subluxation or dislocation • No current involvement in formal shoulder exercise program Age • PNF: mean (SD) = 21.9 (1.93) y • Control: mean (SD) = 20.7 (1.6) y Gender: unknown	Body part: shoulder Warm-up for 2 min with an Airdyne bicycle using only the arms (both groups) PNF • RC of shoulder patterns (D1 and D2) • 3 sets × 10 repetitions (first with 50% maximum voluntary effort, second with 75% maximum voluntary effort, and third with 100% maximum voluntary effort) • 1-min rest between sets • 90-s rest between exercise patterns • 3 times/wk for 5 wk • D1: shoulder extension–abduction–internal rotation • D1: shoulder flexion–adduction–external rotation • D2: shoulder extension–adduction–internal rotation • D2: shoulder flexion–abduction–external rotation Control • Act as usual • No participation in any form of upper-extremity exercise training • 5 wk	Outcome measures relevant to this review • Active repositioning acuity • Target position: 30° internal rotation, 30° external rotation, 75° external rotation • Storage time: 10 s Measurement side: dominant side Measurement posture • Supine • 90° shoulder abduction and elbow in 90° flexion Measurement method • Absolute error • LIDO Multi-Joint II isokinetic dynamometer (Loredan Biomedical, Inc, Sacramento, CA, USA) • Dynamometer speed of 300°/s (no resistance during rotation) • Electrogoniometer of the isokinetic dynamometer Repetitions for the measure: 3	$\eta^2 = .035$ (between-group difference in postintervention score, 30° internal rotation) $\eta^2 = .063$ (between-group difference in postintervention score, 30° external rotation) $\eta^2 = .035$ (between-group difference in postintervention score, 75° external rotation)
Streepey et al ²⁷ Not responded	Quasi-RCT	n = 18 • PNF (n = 9) • Control (n = 9) Eligibility: Healthy individuals (free from current injury and no history of serious injury requiring surgery to the knee of their dominant side) Age: 18–30 y Gender: 10 women and 8 men	Body part: knee PNF • CR stretching of the quadriceps and hamstring (stretching for 30 s with mild discomfort, isometric contraction for 10 s, and then 30-s resting × 3 sets with a 30-s break) • Hip extension with knee flexion for quadriceps stretching • Hip flexion with knee extension for hamstring stretching Control • Sham passive movement (passive movement of the hip into flexion with knee extension and passive movement of the hip into extension with knee flexion without either mild discomfort or isometric contraction)	Outcome measure relevant to this review • Kinesesthesia of the knee from a 135° angle between the thigh and lower leg Measurement side: dominant side Measurement posture: sitting Measurement method • Absolute error • Knee flexion/extension was undertaken at a velocity of 0.4°/s Repetitions for the measure: 5 knee extension and 5 knee flexion in random order	$\eta^2 = .22$ (interaction effect) $\eta^2 = .012$ (between-group difference in postintervention score)

(continued)

Table 1 (continued)

Study/ corresponding author responded or not (including not contactable)	Design	Participants	Interventions relevant to this review	Measures	Effect size of intervention in comparison with a control condition (methods of effect size calculation)
Minshull et al ²⁸ Not responded	RCT	n = 18 • PNF (n = 9) • Control (n = 9) Eligibility • Healthy individuals • Recreational sports participants (3 times/wk) without systematic flexibility or strength training Age • PNF: mean (SD) = 20.3 (2.2) y • Control: mean (SD) = 20.7 (2.3) y Gender: 18 men	Body part: knee PNF • CRAC of the hamstring (isometric contraction of hip extension and knee flexion for 10 s, 5-s resting, and 10-s active assisted hip flexion with knee extension × 3 sets with a 60-s break) • 2 times/wk for 8 wk Control • Passive stretching of the hamstring (10-s static stretching, 5-s resting, and 10-s static stretching × 3 sets with a 60-s break) • 2 times/wk for 8 wk	Outcome measures relevant to this review • Active repositioning acuity • Target position: 160° angle between the thigh and lower leg • Storage time: unknown Measurement side: preferred side Measurement posture: prone Measurement method • Percentage relative to the target angle of knee flexion [(observed performance score – target per- formance score)/(target perfor- mance score) × 100%] ^a • Instrument with dynamometer • Repetitions for the measure: 5	$\eta^2 = -.0004$ (between-group difference in postintervention score)
Sookhee and Hohee ²⁹ Not responded	RCT	n = 54 • PNF (n = 26) • Control (n = 28) Eligibility • Patients with nonspecific low back pain • Age between 19 and 65 y • Exclusion criteria: structural differences in lower-extremity, pathological findings of tumors, a history of surgery for severe trauma, a rheumatoid disease, a neurological problem, recent treatment to relieve pain or medi- cation, treatment in a large hospital within the past 3 mo, or an exercise habit of > 3 d/wk Age • PNF: mean (SD) = 58.0 (32.1) y • Control: mean (SD) = 60.8 (30.2) y Gender: unknown	Body part: lower-extremity Warm-up with hyperthermia treatment for 20 min (both groups) PNF • RC (lower-extremity flexion–adduc- tion–external rotation with knee flexion, sprinter, lifting) ^a • 10-s exercise and 10-s rest • 3 sets × 4 times/wk for 6 wk Control • Stabilization exercise (supine, bridge, quadruped, standing position) • 10-s exercise and 10-s rest • 3 sets × 4 times/wk for 6 wk	Outcome measures relevant to this review • Active repositioning acuity • Target position: 30° trunk flex- ion • Storage time: a few seconds • Follow-up: 3-wk postinterven- tion (follow-up 1) and 6-wk postintervention (follow-up 2) Measurement side: not applicable Measurement posture: standing Measurement method • Angle at Th12 spinal process ^a • Digital goniometer Repetitions for the measure: 3	$\eta^2 = -.006$ (between-group difference in postintervention score, follow-up 1) $\eta^2 = .0009$ (between-group difference in postintervention score, follow-up 2)

(continued)

Table 1 (continued)

Study/ corresponding author responded or not (including not contactable)	Design	Participants	Interventions relevant to this review	Measures	Effect size of intervention in comparison with a control condition (methods of effect size calculation)
Cho et al ⁶ Not responded	RCT	n = 40 • PNF (n = 19) • Control (n = 21) Eligibility: healthy individuals (free from orthopedic abnormali- ties and no history of knee injury) Age • PNF: mean (SD) = 20.2 (0.9) y • Control: mean (SD) = 20.3 (1.3) y Gender • PNF: 9 women and 10 men • Control: 10 women and 11 men	Body part: knee PNF • CR of the hamstring at 90° knee flexion (isometric contraction of knee flexion for 7 s and then 5-s resting × 3 sets) • CR of the quadriceps at 90° knee flexion (isometric contraction of knee extension for 7 s and then 5-s resting × 3 sets) • 10 s between the 2 different CR interventions Control • Without interventions	Outcome measures relevant to this review • Active repositioning acuity • Target position: 60°, 90°, 120°, and 150° angle between the thigh and lower leg • Storage time: 5 s Measurement side: unknown Measurement posture: prone Measurement method • Absolute error • Isokinetic muscular strength equipment (CSMI) Repetitions for the measure: unknown	$\eta^2 = .28$ (between-group difference in postintervention score, a target of 60°) $\eta^2 = .20$ (between-group difference in postintervention score, a target of 90°) $\eta^2 = .14$ (between-group difference in postintervention score, a target of 120°) $\eta^2 = .19$ (between-group difference in postintervention score, a target of 150°)
Furuya et al ³⁰ Responded	RCT	n = 30 (from 19 patients) • PNF (n = 14) • Control (n = 16) Eligibility • Patients undergoing knee ar- throplasty (3 wk after the surgery) • Exclusion criteria: diseases of central nervous system, history of medical diagnosis in the back or hip, unable to flex the knee >90°, unable to extend the knee >45°, exclusion from a postsurgical protocol (walk training after the next day of the surgery and dis- charging at 3 wk after the surgery) Age: mean (SD) = 72.4 (5.2) y Gender: 16 women and 3 men	Body part: knee PNF • Replication of hip flexion–adduction– external rotation pattern with minimiz- ing hip movements in sitting (45° knee extension from 90° flexion × 5 sets) Control • Active knee extension (45° knee extension from 90° flexion × 5 sets)	Outcome measures relevant to this review • Active repositioning acuity • Target position: 135° angle between the thigh and lower leg • Storage time: 5 s Measurement side: surgical side Measurement posture: sitting Measurement method • Absolute error • Analysis of static image from a side view using Image J Repetitions for the measure: 5	$\eta^2 = .08$ (interaction effect) $\eta^2 = .02$ (main effect of intervention)
Ito et al ³¹ Responded	RCT	n = 18 • PNF (n = 9) • Control (n = 9) Eligibility: healthy individuals (no history of knee injury) Age: mean (SD) = 35.3 (7.5) y Gender: 9 women and 9 men	Body part: knee PNF • Replication of hip flexion–adduction– external rotation pattern with minimiz- ing hip movements in sitting (45° knee extension from 90° flexion × 5 sets) Control • Active knee extension (45° knee extension from 90° flexion × 5 sets)	Outcome measures relevant to this review • Active repositioning acuity • Target position: 135° angle between the thigh and lower leg • Storage time: 5 s Measurement side: dominant side Measurement posture: sitting Measurement method • Absolute error • Analysis of static image from a side view using Image J Repetitions for the measure: 5 repetitions	$\eta^2 = .28$ (between-group difference in prechange to postchange scores)

Abbreviations: CR, contract-relax; CRAC, contract-relax-antagonist-contraction; PNF, proprioceptive neuromuscular facilitation; RC, repeated contraction; RCT, randomized controlled trial.

^aDifficult for clear understanding from the original paper.

Table 2 Methodological Quality

Study	PEDro criteria											Additional criteria					PEDro total from criteria 2 to 11 (/10)	Total (/16)
	1	2	3	4	5	6	7	8	9	10	11	A	B	C	D	E		
Lazarou et al ⁵	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1	9	13
Bjorklund et al ²⁶	1	1	0	1	0	0	0	1	0	1	1	1	0	0	1	0	5	8
Padua et al ⁷	0	1	0	1	0	0	0	1	0	1	1	1	0	0	1	0	5	7
Streepey et al ²⁷	0	0	0	1	0	0	0	1	0	1	1	1	0	0	1	0	4	6
Minshull et al ²⁸	0	1	0	1	0	0	0	0	0	1	1	1	0	0	0	0	4	5
Sookhee and Hohee ²⁹	1	1	0	1	0	0	0	0	0	1	1	0	0	0	0	0	4	5
Cho et al ⁶	1	1	0	0	0	0	0	1	0	1	0	1	0	0	0	0	3	5
Furuya et al ³⁰	0	1	0	0	0	0	1	0	0	1	1	0	0	0	0	0	4	4
Ito et al ³¹	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	3	3

Note: A greater total score generally indicates a better methodological quality (0 = not satisfied and 1 = satisfied).

Reporting criteria: 1, eligibility criteria; 2, random allocation; 3, concealed allocation; 4, baseline comparability; 5, subject blinding; 6, therapist blinding; 7, assessor blinding; 8, follow-up; 9, intention-to-treat; 10, between-group statistical comparisons; 11, measures of variability; A, approval from the ethics committee and informed consent; B, trial registration; C, inclusion of an adequate sample size; D, reliability of the outcome measures; E, appropriate statistical assessment with effect size calculation.

thus, the effect size was calculated based on the within-group change scores. Statistically, an effect size calculated using the within-group change scores is considered more accurate than that calculated using the postintervention scores. Therefore, a promising intervention in a future trial may be a replication, and this would not be surprising considering findings in previous studies that investigated brain area facilitated by PNF.^{12,13} The replication includes rotational elements of joint movements, and all previous studies that demonstrated enhanced activities of the superior parietal cortex and cerebellum^{12,13} used PNF techniques with rotational elements. Therefore, rotational elements of movements may be a key factor for PNF techniques to enhance the JPS, and future studies are required.

Regarding participants, the 2 studies with a large effect size^{6,31} recruited healthy individuals. When we explored the possibilities of enhancing the performance in activities that require fine motor control with PNF, a study involving healthy individuals may be considered. By contrast, although Furuya et al³⁰ and Ito et al³¹ used replication targeting the knee, Furuya et al³⁰ did not detect an effect size as large as that in Ito et al's study.³¹ This difference may have been associated with the difference in the recruited participants because Furuya et al³⁰ recruited patients undergoing knee arthroplasty, while Ito et al³¹ recruited healthy individuals. When we explored effective interventions to improve impaired JPS, a trial with participants with more preserved mechanoreceptors than that in patients undergoing knee arthroplasty would be demanded. It has been known that patients with anterior cruciate ligament injury have impaired JPS,^{32–35} and thus, it may be important to undertake a future trial including patients with anterior cruciate ligament injuries to investigate effect of replication technique on the JPS.

Study Limitations

The current review has 2 limitations. First, the ideal effect size calculation should have been performed with the interaction effect and intervention effect. However, such a statistical analysis was reported by Furuya et al³⁰ only. It was impossible to obtain additional data for the statistical analyses, and effect size calculations were undertaken using the within-group change scores or the postintervention scores in most studies.^{6,7,26–29,31} It can be assumed that the

calculated effect sizes in the current study can be different from the genuine effect sizes. The use of the effect sizes is recommended only for future research designs. Second, there were 2 studies with unclear information regarding the interventions and/or outcomes,^{28,29} where it was impossible to clarify the information from the corresponding authors. We could not reperform these studies, and these results should be cautiously interpreted.

Conclusions

We found that there were no multiple studies with high methodological quality and similar PNF techniques, outcomes, and participant characteristics. More high-quality studies are required to achieve a comprehensive understanding regarding the effect of PNF on the JPS.

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Appendix 1. Search Strategy

(stretching OR “Proprioceptive Neuromuscular Facilitation”) AND (sensorimotor OR proprioception OR “joint position sense”)

Appendix 2. Additional Criteria for the Assessment of the Methodological Quality

[A. Approval from the ethics committee and informed consent]

Have the authors documented the ethical approval for the research and gained informed consent from the participants?

Yes
No or Unable to determine

[B. Trial registration]

Have the authors registered the clinical trial at a clinical trial registry and documented the ID numbers?

Yes
No or Unable to determine

[C. Incursion of an adequate sample size]

Have the authors justified their sample size through a power calculation or post-hoc analysis (and recruited sufficient numbers)?

Yes
No or Unable to determine

[D. Reliability of the outcome measures]

Have the authors documented the evidence of the reliability of the outcome measures relevant to this review?

For studies that have provided references of other works regarding reliability or have demonstrated the accuracy of the outcome measures, this question should be answered with yes.

Yes
No or Unable to determine

[E. Appropriate statistical assessment with effect size calculation]

Did the authors use appropriate statistical analyses for evaluating the results as per their aim, and have they documented the effect size?

When a repeated-measures ANOVA with effect size for parametric analysis and Mann–Whitney *U* test using pre–post difference with effect size is used, this question should be answered with yes.

Yes
No or Unable to determine