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The Effect of Static Stretching and Proprioceptive Neuromuscular Facilitation Stretching in Reducing Delayed Onset Muscle Soreness Among Adults: A Systematic Review

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ABSTRACT

Stretching is typically done as part of a warm-up regimen before training or competition to improve muscle flexibility, and performance and prevent DOMS. Stretching techniques include static, ballistic and proprioceptive neuromuscular facilitation (PNF). Limited data supports the effectiveness of static and PNF stretching in reducing DOMS, despite its perceived ease and safety. Studies indicate stretching had an impact on the decrease of DOMS following physical activity. Additionally, other studies indicate that static and PNF stretching may reduce lower limb performance and may not be effective in reducing DOMS. Thus, this research sought to identify the effect of static and PNF stretching in reducing DOMS among adults. Using online databases such as PubMed, PEDro, The Cochrane Library, and ScienceDirect, a thorough search of the English-language literature was carried out for publications published between 2013 and 2023. Seven relevant articles for review have been identified using these databases. Randomized control trial studies in which the participants were adult population, used static stretching or/and PNF stretching as an intervention and outcomes on perceived muscle soreness and range of motion were included in this review. Subsequently, the publications went through screening based on their abstracts and titles and PICOS criteria were used to assess each article's eligibility. Following that, RoB2 tools were used to evaluate the papers' risk of bias. The information was then examined descriptively. The result of this systematic review study showed that there is a positive effect of static stretching in reducing DOMS among adults. However, the effect of PNF stretching in reducing DOMS among healthy adults is still inconclusive due to the limited number of randomized control trial studies on PNF stretching being conducted.

BACKGROUND OF THE STUDY

Delayed onset muscle soreness (DOMS) is characterized by delayed muscular discomfort, stiffness, loss of muscle force generation capability, decreased joint range of motion (ROM) and diminished proprioceptive function. The inflammation that follows the microtrauma to the muscles is assumed to be the cause of the soreness (Sonkodi et al., 2020). DOMS can disrupt daily activities, athletes' performance, and the ability of people who are not accustomed to exercise to continue exercising for fitness (Mizumura & Taguchi, 2015). DOMS is one of the most prevalent causes of decreased muscle performance in sports and it is related with pain and a reduction in ROM and muscle strength. It is common in both professional and recreational players (Hotfiel et al., 2017).

Researchers have found mixed results when it comes to the benefits of stretching. In healthy adults, muscle stretching does not significantly reduce delayed-onset muscle soreness after exercising (Herbert et al., 2011). Zulaini et al. (2021) had done a study and the findings revealed that stretching and recovery had an effect on the decrease of DOMS following physical exercise.

This study aims to address a gap in knowledge by examining and offering insights into the efficacy of various stretching strategies for minimizing DOMS. Current literature provides conflicting conclusions and is devoid of thorough evidence regarding the efficacy of static and PNF stretching in reducing DOMS among healthy adults. By providing a better understanding of the potential benefits or drawbacks of static and PNF stretching in lowering DOMS, this study seeks to fill this knowledge gap and enlighten researchers and practitioners in the field.

Prodromal calf soreness was experienced by about 20% of patients prior to calf damage (Fields & Rigby, 2016). By reviewing the existing RCT study regarding the effect of static and PNF stretching in lowering DOMS in healthy adults, this study aims to close this knowledge gap and offer useful guidance for practitioners and individuals alike on how to best tailor their stretching regimens for improved muscle recovery. The effect of static and PNF stretching on perceived muscle soreness and ROM will be thoroughly studied through relevant papers or studies.

Regular physical activity and sports have long been recognized for their health advantages. However, exercise can also cause fatigue and damage to the muscles or can be associated with delayed onset muscle soreness (DOMS). It can result in discomfort and stiffness in the muscles that lasts from hours to days following an unusual exercise regimen that mostly consists of eccentric contractions (Ozmen et. al., 2017). DOMS tend to cause pain, decrease muscle strength and joint range of motion (ROM), which can hinder exercise performance while also making daily activities more difficult to perform (Sadacharan & Seo, 2021). In essence, examining the effect of stretching on muscle soreness advances scientific understanding and benefits multiple facets of human health, including recovery, fitness, and general health concerns. It also addresses practical issues associated with exercise. Hence, this systematic review intends to collect evidence regarding the effects of static and PNF stretching on the reduction of DOMS among healthy adults.

Muscle soreness that is severe or persistent may discourage people from engaging in regular physical activity, especially for athletes or fitness enthusiasts which could have an impact on their fitness objectives and general health. Afonso et al. (2021) mentioned that stretching is often recommended to alleviate the symptoms of DOMS following physical exertion. Therefore, this research sought to identify the effects of two different type of stretching which are static and PNF stretching on the reduction of DOMS.

Static stretching is a frequent warm-up technique intended to increase the ROM and possibly avoid injuries (Takeuchi & Nakamura, 2020). Static stretching entails bringing single or many joints to the limit of their ROM through active contraction of the muscles that are acting as agonists or through the use of external forces such as the force of gravity, other people or stretching devices such as stretch bands. In the final position, the individual keeps the muscle extended for a predetermined amount of time (Chaabene et al., 2019). For most people, static stretching should be done two to three times a week accompanied by an active warm-up, in accordance with the American College of Sports Medicine (2023). Hold each stretch for 15-30 seconds and repeat two to four times (Steber, 2022).

Bernhart (2013) stated that there are two main ways to do static stretching which are active and passive. Active stretching happens when the individual uses their own muscles to hold the stretch position. This type is better for improving active flexibility. Passive stretching involves an outside force holding the stretch for the individual, like an object or another person. With passive stretching, it is unnecessary to contract the opposing muscle while stretching. In active static stretching, the opposing muscle groups are contracted through reciprocal inhibition, while in passive static stretching, both the antagonist and agonist muscles might relax during the stretch.

Shaha et al. (2021) mentioned that PNF is being used in clinical settings by physiotherapists to regain functional ROM and build strength in patients who are suffering soft tissue damage. The contract-relax method (CR) and the contract-relax-antagonist-contract method (CRAC) of PNF appear much more frequently in the scientific research than others.

The CR method required the individual to lengthen the target muscle (TM) and hold that position while contracting the TM to its fullest isometrically for a specified duration. This was often accompanied by a brief relaxation of TM that included a passive stretch (Shaha et al., 2021).

The CRAC method used the same procedures as the CR technique but went one step further. In lieu of just stretching the TM passively, the individual contracted the antagonist muscle for the remaining time. When used in combination with exercise, PNF stretching is also believed to improve muscular performance. It has been shown to boost muscular performance when done after or without exercise for at least two sets of PNF every week (Howell, 2018).

METHODOLOGY

3.1 METHODOLOGY

The systematic review approach was implemented in this research project. The systematic review consists of several components which incorporate formulation of research question, establishing inclusion and exclusion criteria, strategy for searching, searching databases, registering protocols, creating titles, abstracts, screening full texts, manually searching, extracting data, quality assessment, data verification, statistical analysis, double data verification, and writing manuscripts (Mohamed Tawfik et al., 2019). A guideline to conduct systematic review which follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was employed. The PRISMA guideline is divided into four steps which are identification, screening, eligibility and included the pertinent studies which can be illustrated in Figure 3.1.

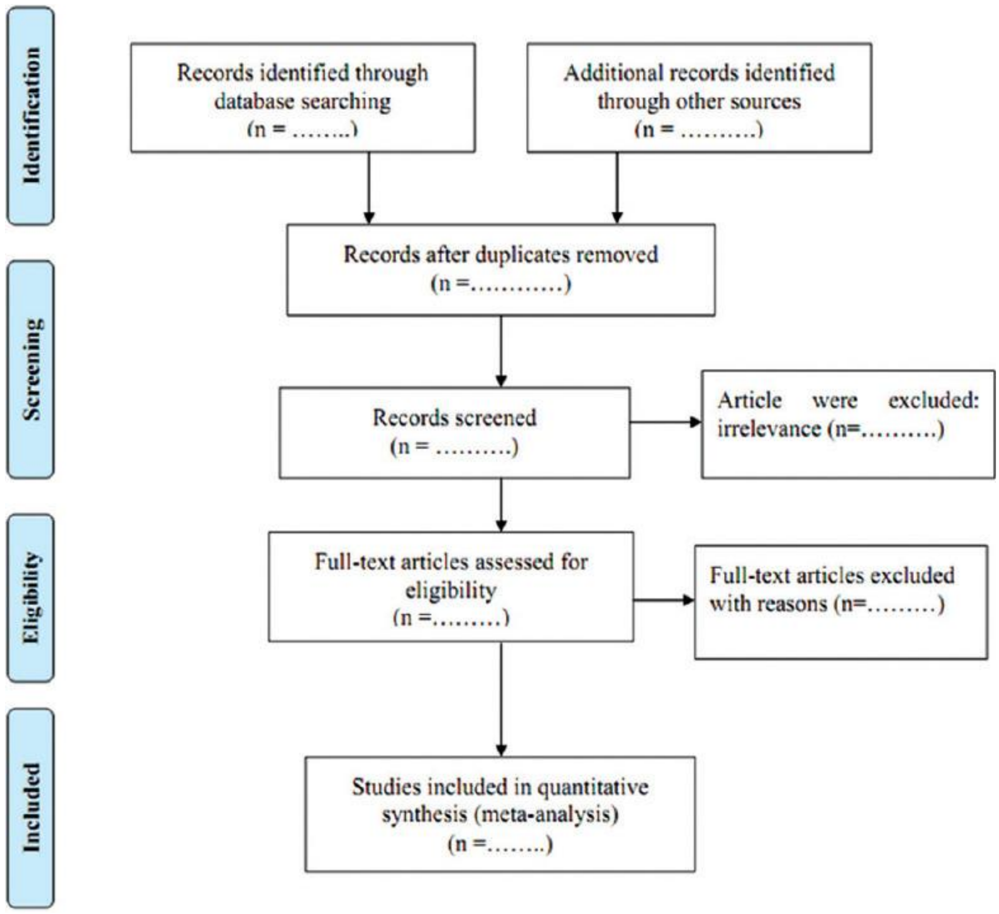

Figure 3.1: Screening process and articles selection according to the PRISMA Guidelines

3.2 SEARCH STRATEGY AND IDENTIFICATION

Online databases such as PubMed, Physiotherapy Evidence Database (PEDro), The Cochrane Library and ScienceDirect databases was utilized to look for the relevant studies. The Boolean Operators, which are simple terms like 'AND,' 'OR,' and 'NOT,' was employed in the search process. The specific keywords was used to identify the relevant articles related to the study such as ‘static stretching’ OR ‘proprioceptive neuromuscular facilitation stretching’ OR ‘PNF stretching’ ‘contract relax stretching’ OR ‘hold relax stretching’ OR ‘stretching’ AND ‘delayed onset muscle soreness’ OR ‘muscle soreness’ AND ‘adults’. The identified studies were documented.

3.3 SCREENING

The screening process of the journals’ title, abstract and the full text was conducted hinged on the inclusion and exclusion criteria, as shown in Table 6.2. After screening the research paper or article, it was decided whether to include or exclude the study. The article that was still pertinent to the objective of the study and research question were reviewed. The unrelated articles that have been excluded were based on exclusion criteria and the rationale for the articles’ exclusion will be illustrated in Table 3.3.

Table 3.3 Inclusion and Exclusion Criteria

Inclusion Criteria
Studies involved adults, aged between 18 to 50 years old
Studies that used stretching exercise included static and/or PNF stretching

Studies that used perceived muscle soreness and/or range of motion as outcome measures
Studies with randomized control trial study
Studies that are written in the English language
Studies published from 2013 and above

Exclusion Criteria
Studies with systematic literature reviews and qualitative studies design

3.4 ELIGIBILITY CRITERIA

Problem, Intervention, Comparison, Outcome and Study (PICOS) criteria was employed to assess the eligibility of the research paper that have been prescreened. The PICOS criteria are stated in Table 3.4.

Table 3.4 PICOS Criteria

PICOS Criteria	
Population (P)	Adults
Intervention (I)	Static stretching, PNF stretching
Control (C)	No stretching
Outcome (O)	Perceived muscle soreness, Range of motion of any part of the body
Study Design (S)	Randomized control trial study

3.5 QUALITY ASSESSMENT/ RISK OF BIAS

For the purpose of obtaining more accurate and pertinent data, the Revised Cochrane risk-of-bias tool for randomized trials (RoB 2) was utilized as a risk-of-bias assessment tool prior to reporting the results of the study. Randomized trials can benefit from this tool when assessing potential biases. Five domains have been included in this instrument: 1) the procedure of randomization; 2) sixteen deviations from planned interventions; 3) missing result data; 4) outcome measurement; and 5) the selection of reported outcomes.

3.6 REPORTING RESULT/ DATA EXTRACTION

All the data extracted was defined priori. By constructing a table, it was easier to gather information regarding the author, year of publication, study design, risk of bias, number of participants and outcome measure in a systematic manner.

RESULTS

4.1 STUDY SELECTION

EndNote was utilized to save and arrange the articles in the process of choosing the relevant study. In total, 1525 articles from four databases were retrieved during the initial literature search, mainly hailing from PubMed (n=420), PEDro (n=108), The Cochrane Library (n=147) and ScienceDirect (n=850). No additional records were identified through other sources. Subsequently, duplicates are removed to get the overall number of studies, which comes out to 1511 articles. The papers' titles and abstracts were looked at to ensure they fulfilled the established inclusion criteria. 1489 articles were removed after being screened for the title and abstract since they were considered irrelevant to the study. Next, the remaining 22 publications were assessed using the aforementioned list of inclusion and exclusion criteria.

Following the last screening, 15 articles were removed, resulting in the inclusion of the remaining seven full-text articles in this systematic review.

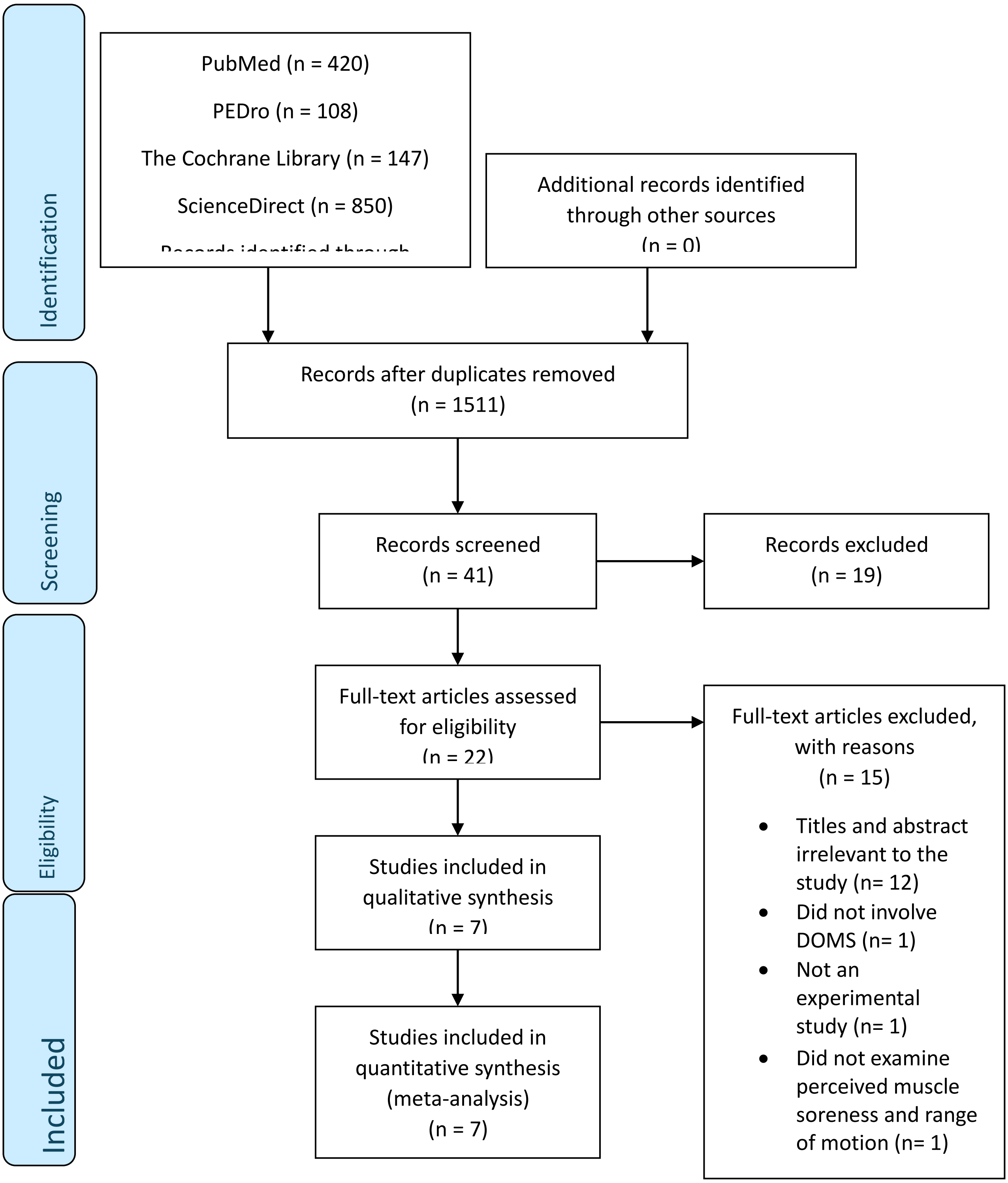

Figure 4.1: PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) flow diagram of each stage of the study selection

4.2 STUDY CHARACTERISTICS

The study contained seven articles, all of which were randomized control trials (RCT). Participants in these publications varied from 25 to 60 participants, with ages ranging from 18 to 45 years old. They are all made up of a healthy adult population, including both ordinary people and those who are active. The interventions utilized in these seven articles were static and PNF stretching. Some studies comprised both static and PNF stretching, such as Sohail et al. (2022), Xie et al. (2017), Cha et al. (2015) and McGrath et al. (2014), while others consisted solely of static stretching, such as Apostolopoulus et al. (2018), Leslie et al. (2017) and Chen et al. (2015). Table 4.1 displays information about participants, interventions, outcome measures and results of these studies.

Table 4.2: Characteristics of Included Studies

Author/Year	Study design	Participants Inclusion criteria Study settings	Intervention	Outcome Measures	Results
Sohail et al. (2022)	RCT	Participants N=48 Inclusion criteria 1) Age 18-45 years 2) DOMS in calf muscles 3) No known musculoskeletal disease 4) Pain rating 3 to 8 on numerical pain rating scale (NRS) Lower extremity functional scale (LEFS) score in range of 26 to 79 Study settings Gyms of Faisalabad,	Intervention group Group A (n=16) • Static stretching of calf muscles; 10 repetitions with resting period of 10 sec in between, twice per day for 5 days, holding each stretch for 30 sec Intervention group Group B (n=16) • PNF stretch of hold relax–hold; the hold phase lasting 8 sec and relaxation phase of 10 sec, performed	• VAS • Ankle range of motion (ROM)	• Significant difference in dorsiflexion ROM measurement for three groups at day 3 post–treatment reading and day 4 and 5 ($p < 0.05$). Significant group differences for PNF group in dorsiflexion ROM in the follow up sessions ($p < 0.05$) on day 2, 3, 4 and 5 VAS score • Significant difference in VAS scores

		including Al Fahad Gym, Golds gym, Boulevard Gym, and Zain Gym	15 repetitions in one set for 5 days Control group (n=16) • No intervention		at day 2, 3, 4 and 5 follow up session between the 3 groups ($p < 0.05$). Significant group differences for VAS in PNF group in the follow up sessions ($p < 0.05$) on day 3, 4 and 5 • PNF stretching more effective than static stretching in reducing pain and improving range of motion of the ankle
Apostolopoulos et al. (2018)	RCT	Participants N=30 Inclusion criteria Age: 25 ± 6 years Mass: 83.1 ± 10.7 kg Height: 1.78 ± 0.68 m Actively involved in resistance training on a regular basis and	Intervention group (n=10) **High-intensity (70%–80% maximum perceived stretch) group** Intervention group	• VAS/numerical rating scale	• Statistically significant main effect of time on perceived muscle soreness values after an unaccustomed eccentric exercise bout was observed ($p < 0.001$),

		were familiar with the concept of performing maximal contractions. Study setting	(n=10) **Low-intensity (30%–40% maximum perceived stretch) group** Both stretching groups performed 3 sets of passive static stretching exercises of 60 s each for hamstrings, hip flexors, and quadriceps, over 3 consecutive days, post-unaccustomed eccentric exercise Control group (n=10) No intervention given post-unaccustomed eccentric exercise		suggesting a reduction in perceived muscle soreness values over time regardless of condition • However, low intensity passive static stretching may lower perceived muscle soreness to a greater extent compared with high-intensity passive static stretching and control at 72 h post-unaccustomed eccentric exercise **Low-intensity passive static stretching versus high-intensity passive static stretching** • low-intensi

					ty passive static stretching resulted in a likely small beneficial reduction in perceived muscle soreness immediately following unaccustomed eccentric exercise (time 0) to 24 h, an unclear effect between 24–48 h, and a likely moderate beneficial reduction in muscle soreness compared with high-intensity passive static stretching between 48–72 h **Low-intensity passive static stretching versus control** • Low-

					intensity passive static stretching resulted in likely small and very likely large beneficial decrease in perceived muscle soreness from immediately post-unaccustomed eccentric exercise to 24 h and 72 h after, respectively **High-intensity passive static stretching versus control** • Unclear between all assessment timepoints
Xie et al. (2017)	RCT	Participants N=48 Inclusion criteria Healthy individuals without calf muscle	Intervention group (n=16) **Dynamic contract-relax group** • Dynamic	VAS (muscle soreness) ROM	• No statistical differences in muscle soreness between the

		soreness and any other musculoskeletal disorders No exercise participation a week before the study Study setting Research laboratory	contract relax stretching for gastrocnemius and soleus on the dominant leg, 10 times with 10-second rests in between sets, performed twice per day for 5 consecutive days Intervention group (n=16) **Static stretching group** ● Static stretching for gastrocnemius and soleus on the dominant leg, hold for 30 seconds with 10-second intervals and repeated 10 times, twice a day for 5 days Control group (n=16) No		DS, SS, and control groups ● No differences in ROM were found between the DS, SS, and control groups at any time point.

			intervention given		
Leslie et al. (2017)	RCT	Participants N=25 Inclusion criteria Height: 173.8 ± 7.8 cm; weight: 68.6 ± 16.5 kg; age: 22.5 ± 4.2 years with a range of 19–34 years). Study setting University of Saskatchewan	Intervention group **Flexibility training** (n = 8) • Static flexibility training of the knee flexors was completed 3x/week and 30min/day for 4 weeks (12 sessions) with 48 h of rest between sessions. A supine, straight-leg hamstring stretch was used. Hold duration start with 5 sets of 3-min holds and ending with 3 sets of 5-min holds Intervention group **A single bout of intense eccentric exercise** (n = 9)	Range of motion Soreness (VAS)	Flexibility training and single-bout groups had 47% less soreness at 48 h after the first bout of ECC compared with control ($p < 0.05$). The flexibility training group had 10% less soreness at 48 h after the fourth ECC bout compared with both the single-bout and control groups ($p < 0.05$). The flexibility group decreased in active ROM following the eccentric training phase ($p = 0.001$) but remained significantly greater than baseline

			• A single eccentric bout was completed for 4 weeks with the participants performed the eccentric exercise on a dynamometer for 6 sets of 8 eccentric repetitions of voluntary isotonic contractions of the knee flexors with a load of 80% of isometric MVC with 1 min of rest between sets **Control group** (n=8) No intervention given during a 4-week priming phase All groups then completed 4-weeks of eccentric training.		values (p < 0.01). As for passive ROM, flexibility group decreased in passive ROM following the eccentric-training phase (p < 0.05) but remained significantly greater than baseline values (p = 0.001)
Chen et al.	RCT	Participants	Intervention	• Hamstring	• For ROM, a

(2015)		N=36 Inclusion criteria Age 20.6 ± 2.4 y, height 172.3 ± 4.9 cm, weight 65.8 ± 8.8 kg) with limited passive straight-leg elevation (hip flexion ROM of less than 80° and not involved in any current regular resistance, aerobic, or flexibility training	group **Static active stretching (n=12)** 6 sets of 15 seconds with 15 seconds of rest between sets Intervention group **Dynamic active stretching** (n=12) 15 repetitions (set at a rhythm of 60 beats/min) per set for 6 sets, with a rest period of 15 seconds between sets Control group (n=12) No intervention given After each intervention, all subjects performed 6 sets of 10 maximal eccentric contractions of the dominant-leg knee flexors	flexibility was evaluated using passive straight-leg raises (SLR) • Hamstring muscle soreness (VAS)	significant 2-way interaction (time × intervention) was also noted (P <0 .001). The CON group showed a significant decrease in ROM relative to the SAS (D1–D5) • Hamstring ROM increases after static active stretching compared to control group • For muscle soreness, a significant 2-way interaction (time × intervention) was noted (P < .001). Soreness was significantly smaller in the SAS than in the CON group during the D3-to-D5

			on an isokinetic dynamometer		period after eccentric exercise • Muscle soreness decreases after static active stretching compared to control group
Cha et al. (2015)	RCT	Participants N=60 Inclusion criteria Healthy people without an orthopaedic history age, height, and weight were 20.2 ± 1.4 years, 169.7 ± 5.1 cm, and 59.8 ± 10.2 kg in the hold relax-agonist contraction (HR-AC) group, respectively 21.3 ± 1.2 years, 171.8 ± 9.3 cm, and 62.2 ± 5.4 kg in the PSLR group, respectively	Intervention group **HR-AC group** (n = 30) The investigator passively stretched the held that position for 7 seconds. Next, the subject maximally isometrically contracted the hamstrings for 7 After the contraction, the subject relaxed for 5 seconds. Repeat 20 times.	• Muscle fatigue after DOMS induction • Range of motion of the hip joint after DOMS induction	• Significant increases in hip joint angle was observed between the HR-AC group and the PSLR group ($p < 0.05$) post intervention • Significant decrease in muscle fatigue was observed between the HR-AC group and the PSLR group ($p < 0.05$) post intervention

			Intervention group **Passive straight leg raise (PSLR)** (n=30) • The hamstring muscle was stretched with light, tolerable pain and held for 30 seconds. After the passive stretching, the subject relaxed for 5 seconds. Repeat 20 times.		
McGrath et al. (2014)	RCT	Participants N=57 Inclusion criteria Ages ranging from 18-25 years. Not exercise the lower extremities at least 48 hours prior to their visit.	Intervention group **PNF stretch group** (n=19) • The stretched leg was fully extended on the investigator's shoulder as a passive assist and was elevated until the participant self-reported a maximal	Muscle soreness scale ROM (sit and reach test)	DOMS pain significantly decreased ($p<0.05$) from 24 to 48 hours post-exercise for the PNF and control groups, but not for the static stretch group

			stretch on the hamstrings muscles, then the "contract-relax-agonist contract" PNF stretch protocol was performed; whereby, the participant maximally contracted the hamstrings isometrically for 5 seconds against the shoulder of the PI followed by 5 seconds of rest. Then, the leg moved to a further stretched position of the hamstrings and held it there for 5 seconds. This protocol was repeated twice on both legs with a 4 second break between sets. Intervention group **Static stretch group** (n=20) ● Participants		

			reached toward one foot with both hands, held for 10 seconds with 4 seconds rest between stretches, for 2 sets on both legs. Control group (n=18) • No intervention given		

4.3 ASSESSMENT OF THE INCLUDED STUDIES

All articles were deemed to have a low risk of bias in accordance with the standards outlined in the Revised Cochrane risk-of-bias tool for randomized trials (RoB 2).

Table 4.3: Quality Assessment of Included Studies using RoB2.

	Risk of Bias Domain						
		D1	D2	D3	D4	D5	Overall
Study	Sohail et al. (2022)	+	+	+	+	+	+
	Apostolopoulus et al. (2018)	+	+	+	+	+	+
	Xie et al. (2017)	+	+	+	+	+	+
	Leslie et al. (2017)	+	+	+	+	+	+
	Chen et al. (2015)	+	+	+	+	+	+
	Cha et al. (2015)	+	+	+	+	+	+
	McGrath et al. (2014)	+	+	+	+	+	+

Domains:
D1: Bias due to randomisation
D2: Bias due to deviation from intended intervention
D3: Bias due to missing data
D4: Bias due to outcome measurement
D5: Bias due to selection of reported result

Judgement
High risk
Some concerns
Low risk

4.4 THE EFFECT OF STATIC AND PNF STRETCHING IN REDUCING DOMS

Seven studies included in this systematic review examined the effect of static stretching in reducing DOMS whereas four studies explored the effect of PNF stretching in reducing DOMS. The studies by Sohail et al. (2022), Apostolopoulos et al. (2018), Xie et al. (2017), Leslie et al. (2017), Chen et al. (2015), Cha et al. (2015) and McGrath et al. (2014) utilized static stretching while the studies by Sohail et al. (2022), Xie et al. (2017), Cha et al. (2015) and McGrath et al. (2014) only incorporate PNF stretching as their other intervention along with static stretching. The perceived muscle soreness was the same outcome measure utilized in six studies along with the range of motion of various joints. However, there was only a single study that employed perceived muscle soreness without measuring the range of motion, and it was written by Apostolopoulos et al. (2018). Conversely, a study by Cha et al. (2015) only includes ROM without measuring perceived muscle soreness as their outcome measure in their study. Static stretching was reported to have a significant result of reduction in perceived muscle soreness and improvement in range of motion. It was reported in three studies (Sohail et al., 2022; Leslie et al., 2017; Chen et al., 2015). The study conducted by Apostolopoulus et al. (2018) showed a significant decrease in the perceived muscle soreness after the application of static stretching. However, the study did not address the effect of static stretching on range of motion because it did not employ range of motion as an outcome measure. On the other hand, both the Sohail et al. (2022) study and the Cha et al. (2015) study obtained significant results after administering PNF stretching to participants, with both studies demonstrating a substantial improvement in range of motion. However, for perceived muscle soreness, only a study by Sohail et al. (2022) showed a significant reduction in perceived muscle soreness. Static and PNF stretching was utilized as the intervention in studies by Xie et al. (2017) and McGrath et al. (2014), however, neither study showed any improvement in perceived muscle soreness or range of motion. As both Apostolopoulus et al. (2018) and Cha et al. (2015) did not use ROM and perceived muscle soreness as their outcome measures respectively, there is no outcome or effect of static and PNF stretching on DOMS symptoms mentioned in both studies.

DISCUSSION AND CONCLUSION

5.1 THE EFFECT OF STATIC AND PNF STRETCHING IN REDUCING DOMS AMONG ADULTS

The purpose of this systematic review was to determine whether static and PNF stretching may alleviate DOMS in healthy adults. The study by Sohail et al. (2022), Leslie et al. (2017) and Chen et al. (2015) reported that static stretching appears to be effective for perceived muscle soreness reduction and improvement in range of motion ($p < 0.05$). Similarly, the study by Cha et al. (2015) that utilized static stretching as their intervention for the participants showed a significant improvement in range of motion

($p < 0.05$). Moreover, Apostolopoulus et al. (2018) found out that static stretching has a significant difference on perceived muscle soreness ($p < 0.001$).

Apostolopoulus et al. (2018) in their study, also focused on the intensity to perform stretching and it is discovered that the group that received low intensity static stretching experienced significant reduction in perceived muscle soreness that was measured by VAS score compared to the groups that receive high intensity static stretching and control group. In terms of PNF stretching, out of four studies, two studies; Sohail et al. (2022) and Cha et al. (2015) showed significant improvement in range of motion ($p < 0.05$). However, for outcome measure of perceived muscle soreness, only Sohail et al. (2022) reported significant results of reduction in perceived muscle soreness ($p < 0.05$).

On the other hand, a study by Xie et al. (2017) who prescribed static and dynamic contract-relax stretching found no significant reduction in the perceived muscle soreness and range of motion compared to non-intervention group. The ineffectiveness of PNF stretching in lowering DOMS in healthy adults could be attributed to the existence of additional factor that exacerbate and initiate DOMS symptoms. The dosage of the intervention, which includes total duration (number of repetitions), duration of stretch held, intensity (to a point of pain or no discomfort), and stretching position, could be a contributing factor to why dynamic contract relax stretching is unable to reduce DOMS symptoms. This research also indicates that the intramuscular connective tissue may not lengthen as a result of either dynamic contract-relax stretching or static stretching whereby it is ineffective in improving ROM of the ankle. Another study by McGrath et al. (2014) also found that post-exercise PNF stretching does not significantly reduce DOMS. Indeed, according to the statistical analysis, some participants may have had increased DOMS as a result of the pre-stretch muscle contractions of the post-exercise PNF protocol, which put more strain on already injured muscles.

5.2 CONCLUSION

The conclusion that static stretching is an effective intervention for reducing delayed-onset muscle soreness (DOMS) is supported by the synthesis of existing data from several trials. The results show that static stretching has a positive effect in reducing DOMS among healthy adults following exercise. The strength of the evidence and the overall quality of the included studies all support these findings. It is noteworthy that static stretching is effective, indicating that it may be an effective method for reducing DOMS in a variety of situations. However, future research could lead to a more thorough understanding of the significance of static stretching in DOMS management, including studies into the best stretching regimens and their long-term effects.

The available data from several studies, when combined, yields an uncertain conclusion regarding the effectiveness of PNF stretching in reducing DOMS among healthy adults. Determining the exact effect of PNF stretching on DOMS is difficult due to inconsistent data among the included research, as revealed by the findings. This uncertainty is exacerbated by variations in study methodology. The evidence supporting this effect is still inconclusive, as two of the analyzed RCT studies show no improvement in ROM, while the other two show improvement in ROM. Regarding perceived muscle soreness, only one RCT study found that PNF stretching was effective in reducing DOMS by demonstrating a reduction in perceived muscle soreness. Whereas another two RCTs reported no reduction in perceived soreness. According to this study, RCT research on the effectiveness of PNF stretching in lowering DOMS in healthy adults are currently lacking. Therefore, it is necessary to conduct more studies with larger sample sizes and established methods to clarify the effect of PNF stretching in alleviating DOMS and to offer more conclusive evidence for its efficacy.

5.3 LIMITATIONS OF THE STUDY

Several limitations are present in the current study. Firstly, there was a limited number of PNF stretching-related publications that were analyzed. This is due to the lack of RCT studies on the benefits of PNF stretching for the symptoms of DOMS, including perceived muscle soreness and ROM. Secondly, it is challenging to generalize our results because the subjects involved were only healthy adults. Thirdly, additional outcome measures, such as muscle strength, should consider to be included. Forthly, the other type of stretching should also be included in this study such as dynamic stretching. Finally, there is the potential that some relevant papers in other databases were missed because this review focused solely on three databases: PubMed, PEDro, The Cochrane Library and ScienceDirect.

5.4 RECOMMENDATIONS FOR FUTURE RESEARCH

In light of the current findings, a number of recommendations are made for future research. More investigation and research are needed to determine how stretching affects DOMS symptoms in people of all ages, but particularly in the elderly. In addition, future studies should examine the effects of various stretching techniques on DOMS and identify the most beneficial technique.

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