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Systematic Review

Effects of Different Physical Therapy Interventions in Improving Flexibility in University Students with Hamstring Tightness - A Systematic Review and Network Meta-analysis

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ABSTRACT

International Journal of Exercise Science 17(3): 359-381 2024. The aim of the present study was to identify the different interventions for hamstring flexibility among university students with hamstring tightness and to determine the better treatment method. Design: Systematic review and network meta-analysis. An electronic search of the databases: Medline, Pubmed, Cochrane, EMBASE, CINAHL, Physiotherapy Evidence Database (PEDro) was conducted. A total of 11 articles were included in the review. Of these articles, 02 were case-control studies, 02 were interventional pre-post studies and 07 were RCTs. The 07 RCTs were included for network meta-analysis. The findings of the initial network meta-analysis (NMA) which compared control i.e., no intervention with other interventions revealed that all the physical therapy interventions: stretching, electrotherapy combined with stretching, massage, dry needling and neurodynamic exercises combined with stretching and neurodynamics alone were superior to control. Since most studies included stretching as an intervention, a second NMA was conducted to compare the different physical therapy interventions with stretching. The results suggested that US-guided neuromodulation (WMD: -5.80, CI: -12.11, 0.51) had large effects on hamstring flexibility compared to stretching and stretching combined with electrotherapy i.e., cryotherapy and ultrasound (WMD: 0.25, CI: -1.14 to 1.64), MET (WMD: 3.10, CI: -3.28 to 9.48) and massage (WMD: 8.05, CI: -11.90 to 27.18) were inferior to stretching. To further investigate the effects of these interventions three meta-analysis were performed. The results revealed that stretching was more effective (SMD 2.27, 95% 0.72 to 3.81, $p < 0.01$) compared to control (no intervention). Neurodynamic exercises combined with stretching and neurodynamics alone were found to be superior to stretching alone ((SMD -0.69, 95% -1.35 to -0.03, $p < 0.01$) and stretching combined with electrotherapy was not significantly better than stretching alone ((SMD -0.07, 95% -1.00 to 0.87, p=0.88). Neurodynamic exercises combined with stretching and neurodynamics alone showed to be superior to the other physical therapy interventions in improving hamstring flexibility for hamstring tightness among university students, however, the reliability of the evidence is low.

KEY WORDS: Hamstring flexibility, hamstring tightness, physical therapy interventions, stretching, university students

INTRODUCTION

The hamstring muscle group is located in the posterior aspect of the thigh. It comprises three different muscles. This muscle group lies between the hip and the knee posteriorly. The hamstring muscles work on extending the hip and bending the knee joint. Muscle flexibility is the ability of the muscle tissue to lengthen, it is an important factor for health-related physical fitness (21). In terms of physical length or flexibility of a muscle, muscle "tightness" is the inability to elongate and mild to moderate reduction in length (20). Hamstring tightness is described as reduced range of motion (ROM) around a knee and/or hip joint. Also, the individuals may feel tightness in the posterior aspect of their thigh. It is stated to be a major cause for faulty and reduced movement of the hip and the knee among all age groups (16, 45). There are various adverse effects of hamstring tightness in hamstrings. A few of them are reduced range of motion of lower limbs causing alteration in normal gait (13, 14, 42). Also, a few pathological conditions associated with hamstring tightness are plantar fasciitis (6), patellofemoral Pain syndrome (43), and low back pain.

Hamstring tightness is a common musculoskeletal problem observed among university students. The prevalence of hamstring tightness among students aged between 18 – 25 is found to be very high, which is 68% (26). Prolonged sitting is a predisposing factor for tight hamstrings (23). Hamstring tightness may lead to hamstring strain and other injuries which may impede the activities of university students.

During university life, the undergraduates are expected to be seated for long hours (15). There is posterior tilting of the pelvis in sitting position, and continuous knee flexion leading to the hamstring muscles being held in shortened position. During prolonged sitting, the constant shortened position may cause muscle tightness (3). Further, hamstring flexibility may be affected by modifiable factors that include body mass index (BMI), physical activity and non-modifiable factors such as: age and gender (2). Considering the importance of hamstring flexibility in posture and day to day activities, there is a need to identify effective interventions to improve hamstring flexibility for hamstring tightness among young individuals.

There are various studies to determine effective interventions to manage hamstring tightness. Stretching is the main treatment method, however, there are various types of stretching and there are studies that have conducted comparisons to identify the better stretching method. Few forms of stretching interventions are active stretching, passive stretching, manual stretching, proprioceptive neuromuscular facilitation (PNF) stretching etc. In addition, there are other treatment methods such as: electrotherapy, massage, dry needling, neurodynamic exercises used alone or in combination to treat hamstring tightness (10, 24, 27, 32, 39). The application of electrotherapy, massage techniques and dry needling requires the individuals to attend a unit/clinic and spend time and cost to obtain the treatment. It is essential to identify the most effective treatment among the different physical therapy interventions specific to hamstring tightness among university students, to ensure if the time and cost spent by the individuals is worth it. In addition, the identification of the superior intervention with adequate evidence will help in implementation of the better intervention method to gain required outcomes for the best benefit of the individuals.

This systematic review and network meta-analysis (NMA) was conducted to review the past studies including Randomized Controlled Trials (RCTs), case-control, or pre-post studies which were carried out to assess the effectiveness of different physical therapy treatment methods on hamstring flexibility to treat tight hamstrings among university students, to provide a summary of the physical therapy interventions used and the superior treatment methods. The study aimed to provide evidence through network meta-analysis and meta-analysis for the superior treatment method/s. There are no published studies that have conducted a systematic review, network meta-analysis and meta-analysis with the same objective.

METHODS

Protocol and Registration
This review was registered in the International Prospective Register of Systematic Reviews (PROSPERO CRD42022359607). The present systematic followed the Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 (33). The present systematic review and network-meta-analyses were conducted in compliance with the ethical standards set out by the International Journal of Exercise Science (29).

Eligibility Criteria and Study Selection
The study designs included were randomized, case-control and interventional studies with pre-post assessment that included subjects who were university students with hamstring tightness. The included studies must have reported a cut-off value for the outcome measure Active Knee Extension (AKE), Straight Leg Raise (SLR) Test or Sit and Reach Test (SRT) for confirming hamstring tightness. Studies that were not published in English, other communication such as: conference proceedings, editorials, reviews, abstracts, and studies that included athletes that involved in competitive sports as the sample were excluded from this review. Medline, Pubmed, Cochrane, EMBASE, CINAHL, Physiotherapy Evidence Database (PEDro) were the databases used for running the search in the systematic review. The duration of deriving records was carried from 2013 to September 2022. Medical Subject Headings (MeSH) terms, keywords, and text words associated with hamstring tightness, university students and interventions comprised the search strategy. The search strategy is given in the supplementary file. The outcome measure was hamstring flexibility measured by Active knee extension, Straight leg raise test or sit and reach test. Data extraction began with title and abstract screening. This was followed by full-text screening. Each of these stages were carried out by two independent reviewers. Any discrepancies were resolved in the discussion and agreement. The screening process was done in Rayyan (https://www.rayyan.ai).

Risk of Bias
The revised Cochrane "Risk of bias" tool for randomized trials (RoB 2.0) was used to assess the risk of bias (RoB) for randomized controlled studies, it comprises five domains and each domain was assessed (41). For studies that were non- RCT, the National Institutes of Health Quality Assessment Tool for Case-Control and pre-and-post studies (28) was used. The highest level of RoB for each domain was considered to determine the overall RoB.

GRADE Assessment
The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach (17) was used to determine the quality of evidence for the network metanalysis. The overall quality of evidence was graded based on risk of bias, consistency of results, directness, precision, and publication bias (4, 18).

Data Analysis
Initially, RCTs were selected for the network meta-analysis to find out the most effective physical therapy interventions on hamstring tightness among others. Different physical therapy interventions in the included RCTs were categorized into several groups based on the type of intervention i.e., stretching, massage, electrotherapy, dry needling, MET.

MetaXL (www.epigear.com) was used to conduct Network meta-analysis (NMA). It applies the pairwise modelling (DPM) outline for meta-analysis. By assuming a random-effects model, the pooled effect estimates for each comparison were obtained.

For hamstring flexibility, the input data was the post-test mean and standard deviations in each intervention which were directly retrieved from the respective studies. Output data comprised of the weighted mean difference (WMD) and the corresponding 95% confidence intervals (CI). Direct comparisons were obtained within available physical therapy interventions. We used 'control' and 'stretching' as the reference categories for separate NMA. Indirect comparisons were obtained when direct comparisons were not available. Then the interventions were ranked by WMD in the network forest plot.

Further, for each available comparison, WMD with 95% CI was obtained using random-effect models using Review Manager (Rev-Man), Version 5.3 (38). H index was used to assess statistical heterogeneity across pooled direct effect. Weighted pooled H-index was calculated to identify the inconsistency. The cut-off value <3 indicated minimal inconsistency.

RESULTS

Trial Selection
The total number of records identified was 1057; of them 242 duplicates were removed. Further, 815 records were screened for titles and abstracts. Of them, 669 records were excluded. Further, from the 146 records that were screened for full text, 135 articles were excluded, and 11 records

were included as follows: seven RCTs (5, 10, 24, 27, 30, 32, 39), two case-control study (19, 31) and two interventional pre-post studies (8, 34). Figure 1 presents the PRISMA flow diagram.

Traits of Included Studies

The total sample size ranged from 9 to 138 participants, when considering all the studies. The total sample size was 446 with 339 males and 107 females. The identified types of interventions included: stretching (08 studies) (5, 8, 10, 18, 19, 27, 30, 32), electrotherapy (02 studies) (10, 27), neurodynamic exercises (03 studies) (10, 34, 39), dry needling (01 studies) (10), massage (02 studies) (24, 32), MET (01 studies) (30). Table 1 depicts the traits of separate studies.

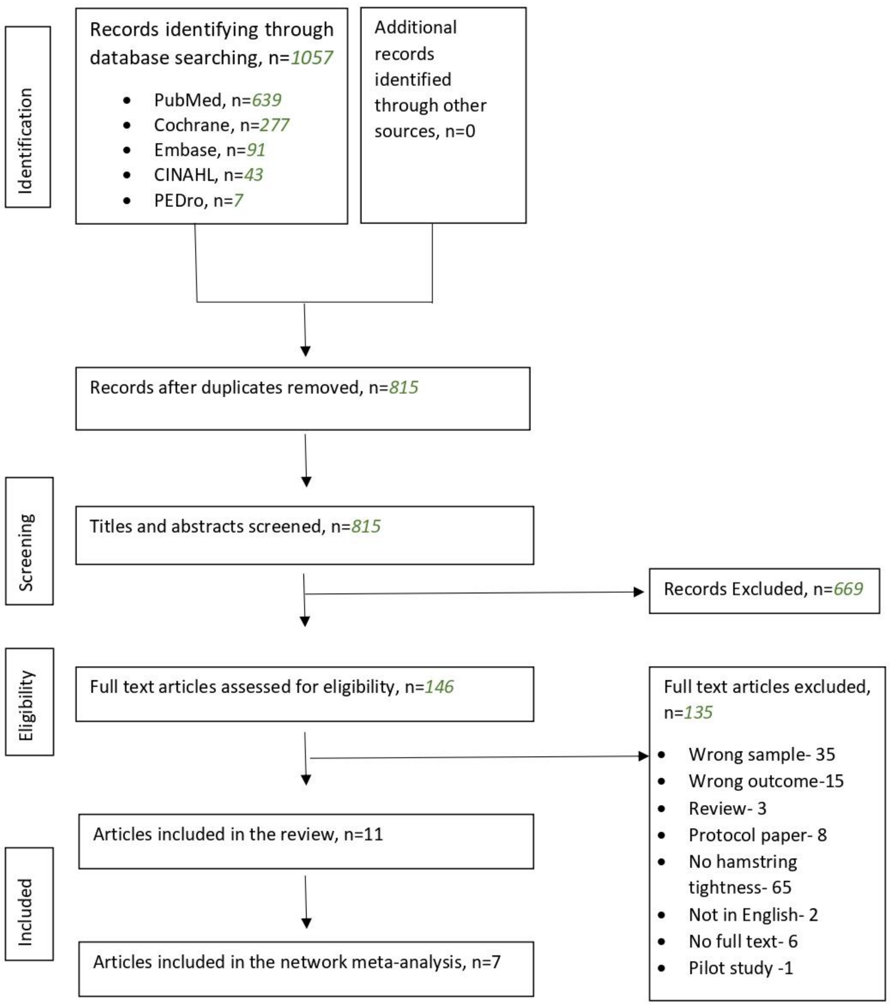

Figure 1. PRISMA flow diagram.

Table 1. Traits of separate studies.

Study	**Sample Size**	**Population**	**Condition**	**Treatments**	**Frequency**	**Duration**	**Intensity**	**Methods**	**Findings**

	Male	Female	ion Charac.						Duration of Interv.	of Outcome Measure	
Nishida et al., 2018 Japan	12	-	Mean ± SD: age - 24.4 ± 2.4years weight- 66.8 ± 6.9kg	decreased hamstring flexibility	low-intensity eccentric exercise	SLDL with no added weight was the low-intensity hamstring ECC-exercise. Three sets of eight repetitions. Three-minute rest between sets.	-	No additional weights	1 session	Passive SLR and APT	APT occurred at a greater muscle length. The hip flexion ROM was improved among subjects who performed low-intensity eccentric exercises.
Naweed et al, 2020 Pakistan	35	-	Mean± SD: Group-A: age - 22.2 ± 2.02 Group-B: age- 19.61 ± 2.95 for	Hamstring tightness	Post Isometric Relaxation	3 sessions per week for 3 weeks	-	-	3 weeks	Sit and reach test, active knee extension test, and Lower extremity functional scale score	Both techniques were equally effective for hamstring flexibility. Further, they were effective for short and long term.
					AIS	3 sessions per week for 3 weeks	-	-	3 weeks		

Ayala et al., 2013 Spain	138	-	Mean age - 21.9 ±1.7 Mean weight- 74.9 ± 8.4 Mean height- 177.4± 8.5	Limited hamstring flexibility males.	Active hamstring stretching exercises	3 days per week. unilateral stretching exercise was performed once and bilateral stretching was performed twice. Stretch duration: 30 secs. 6 sets per session. 20 secs rest between sets.	Total stretch 180 s	-	12 weeks	Passive SLR	Stretching improved hamstring flexibility in males with normal flexibility and those with hamstring tightness
					Control group	No intervention					
Magalhães et al., 2015 Brazil	14	18	Mean age-22.4 years	Hamstring retraction of the right limb	PNF flexibility	3 times per week, 4 repetitions	30-sec hold with 10-sec interval	Pain limiting point	4 weeks	SRT and AKE	PNF along was stated to be convenient and less expensive intervention
					PNF flexibility with cryotherapy	3 times per week, 4 repetitions	20 min cryotherapy. 30-sec hold 10-sec intervals	pain limiting point	4 weeks		
					PNF flexibility with ultrasound thermotherapy	4 repetitions, 3 times per week, 4 weeks	US treatment for 5 minutes 30-sec hold, interval	pain limiting point. US-1Wcm-2	4 weeks		
					Control group	No intervention					

De-la-Cruz-Torres et al., 2021 Spain	40	40	Mean age-22.7 (4.5) years Mean weight-66.1 (8.70)kg Mean height-1.71m (0.08)	bilateral short hamstring syndrome	Passive stretching technique	3 times	30 seconds-stretch (total 1.5 min)	-	1 session	Active SLR	PNM increased SLR on the limb on which intervention was not performed. This cross over effect was seen within 9 seconds.
					Neurodynamic sliding technique	12 repetitions	total 1.5 min	-	1 session		
					US-guided percutaneous neuromodulation (PNM).	10 Hz	total 1.5 min	maximal tolerable intensity	1 session		
Iwata et al., 2019 Japan	12	12	Men age-21.8 years Mean weight-61.3 ± 7.3 kg Mean height-1.67 ± 0.10	Inability to fully extend the knee from starting position	Dynamic stretching (DS)	15 repetitions (30s long sets; 2s stretch* 15 rep)	5 mins	To tolerance with no pain	1 session	Active knee extension and hip flexion	DS led to reduction in passive stiffness. Further, it increased knee ROM.

Pietrzak et al., 2016 UK	9	4	age- 24 (8) years Mean BMI- 23.1±2.8 kg m-2	Tight hamstrings	Novel sciatic-tibial neurodynamic tension technique (MLSS)	2 days with a 3-week break	5 sec, 3 sets, 5 repetitions, 10-sec rest between repetitions, 2-3 min rest between sets	Maximum stretch tolerance with some discomfort	3 weeks	SLR and Knee flexion	MLSS improved muscle extensibility and stretch tolerance.
Osailan et al., 2021 Saudi Arabia	23	-	Age range-19 – 23years Mean Weight- 72.8 ± 17.1 Mean Height- 1.7 ± 0.1 Mean BMI- 23.9 ± 5.1	Hamstring tightness	IASTM for Hamstring muscle	-	2 min	-	1 session	SLR	IASTM improved hip flexion active ROM among subjects with hamstring tightness.
					Manual stretching	3 times	3 min total 30-sec stretch and 30-sec relaxation	-	1 session		

Sharma et al., 2016 India	33	27	Mean age- 22.08 ± 2.29 years Mean weight- 59.50kg Mean height- 163.05cm	Reduced hamstring flexibility	Neurodynamic slider with static stretch. 3 sessions (days 1,4 7)	3 sets: -1st set 10 repetitions	- 2nd set 15 repetitions -3rd set 20 repetitions	30 sec. static stretching. Following stretch, a Neurodynamic slider, held for 1 sec. Speed of movement: Each movement completed in 2 seconds	3 sessions	AKE	Neural sliders and tensioners were equally effective in improving hamstring flexibility. They were performed in addition to static stretching
					Neurodynamic tensioner with a static stretch	3 sessions (days 1,4 7) 3 sets: 1st set 10 repetitions, 2nd set 15 repetitions, 3rd set 20 repetitions	30 sec. static stretching. Following stretch, a Neurodynamic tensioner, held for 1 second	Speed of movement: Each movement completed in 2 seconds	3 sessions		
					Static stretch	3 sessions (days 1,4 7)	30 sec	-	3 sessions		
Lim & Chi-Bok Park, 2019 Korea	14	6	Mean age- 20.21±1.01 Mean weight-	Hamstring tightness	FRV	Foam roller with vibration for 5 rep	1 min for 1 rep total of 10 min	-	1 session	SLR, AKE, and Vertical Jump	FRV was statistically efficient

			63.67± 11.10kg Mean height- 170.34±10.6cm		FRNV	Foam roller with no vibration for 5 times	1 min for 1 rep for a total of 10 min	-	1 session		than FRNV.
Chen et al., 2013 Taiwan	9	-	Mean age- 23.9 ± 3.1 years Mean weight- 64.9 ± 5.2kg Mean height- 174.1 ± 7.1cm	Short hamstrings	Static stretching and PNF and dynamic exercise Unassisted modified hurdler stretch 30 Sec., 30 sec rest, 5 times,	PNF 3 times, 10 sec, 5 sec. rest	-	-	3 sessions. There was a 7-day interval between sessions.	SLR	Stretching improved hamstring flexibility soon after exercise. However, later the peak torque reduced in the SS+PNF group.
					Static stretching and taping and dynamic exercise	Unassisted modified hurdler stretch 30 Sec., 30 sec rest, 5 times, 5cm tape stretched 120% of its original length	-	-	3 sessions. There was a 7-day interval between sessions.		
					No stretching and dynamic exercise	No stretch, been on the plinth for 5-6 minutes	-	-	3 sessions. There was a 7-day interval between sessions.		

Charac-Characteristics, Interv-Intervention, SLDL- Stiff-leg deadlift, SRT-Sit and reach test, US-Ultrasound, APT- Angle of peak torque, PT- Passive torque, ROM-Range of motion, AIS- Active isolated stretch, US- Ultrasound, PNM Percutaneous neuromodulation, IASTM- Instrument-assisted soft tissue mobilization, MLSS- Modified long sit slump, AKE-Active knee extension, SLR-Straight leg raise, FRV-Foam roller with vibration, FRNV- Foam roller with no vibration

Risk of Bias Assessment Procedure

The risk of bias for the seven RCT studies was analyzed using ROB 2.0 tool (5, 10, 24, 27, 30, 32, 39). The specific domains were rated, and the total score was reported. One RCT study (27) was identified with some concerns and the other six studies were reported as low risk (5, 10, 24, 32, 39, 40). The relevant NIH tools were used to assess case-control and pre-post-intervention studies. Assessment identified one case control study as poor (31). While the other was rated as fair (19). Of the two interventional pre-post studies one was rated as fair (8) and the other was rated as good (34). Table 2 shows the results of ROB assessment as a summary. The detailed results of the ROB assessment are shown in Tables 3, 4 and 5.

S.No.	Study	Study Type	Quality Rating
1	Naweed et al, 2020	RCT	Low risk
2	Ayala et al., 2013	RCT	Low risk
3	Magalhães et al., 2015	RCT	Some Concerns
4	De-la-Cruz-Torres et al., 2021	RCT	Low risk
5	Osailan et al., 2021	RCT	Low risk
6	Sharma et al., 2016	RCT	Low risk
7	Lim & Chi-Bok Park, 2019	RCT	Low risk
8	Nishida et al., 2018	Case-control	Fair
9	Iwata et al., 2019	Case-control	Poor
10	Chen et al., 2013	Interventional pre-post study	Good
11	Pietrzak et al., 2016	Interventional pre-post study	Fair

Table 2. Risk of bias assessment summary.
S.No-Study number

Table 3. Risk of bias assessment for randomized controlled trials.

Study (RCT)	Domains						Total score
	1	2.1	2.2	3	4	5	
Naweed et al, 2020	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Ayala et al., 2013	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Magalhães et al., 2015	Some concerns	Some concerns	Some concerns	Low risk	Some concerns	Some concerns	Some concerns
De-la-Cruz-Torres et al., 2021	Low risk	Low risk	Some concerns	Low risk	Some concerns	Low risk	Low risk
Osailan et al., 2021	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Sharma et al., 2016	Low risk	Some concerns	Some concerns	Low risk	Low risk	Low risk	Low risk
Lim & Chi-Bok Park, 2019	Low risk	Some concerns	Low risk	Low risk	Low risk	Low risk	Low risk

Table 4. Risk of bias assessment for case-control studies.

Criteria Number	Criteria	Comment	
		Nishida et al., 2018	Iwata et al., 2019
1	Was the research question or objective in this paper clearly stated and appropriate?	Yes	Yes
2	Was the study population clearly specified and defined?	Yes	Yes
3	Did the authors include a sample size justification?	No	No
4	Were controls selected or recruited from the same or similar population that gave rise to the cases (including the same timeframe)?	Yes	Yes
5	Were the definitions, inclusion and exclusion criteria, algorithms or processes used to identify or select cases and controls valid, reliable, and implemented consistently across all study participants?	NR	Yes
6	Were the cases clearly defined and differentiated from controls?	Yes	No
7	If less than 100 percent of eligible cases and/or controls were selected for the study, were the cases and/or controls randomly selected from those eligible?	No	NR
8	Was there use of concurrent controls?	Yes	No
9	Were the investigators able to confirm that the exposure/risk occurred prior to the development of the condition or event that defined a participant as a case?	Yes	No
10	Were the measures of exposure/risk clearly defined, valid, reliable, and implemented consistently (including the same time period) across all study participants?	Yes	NR
11	Were the assessors of exposure/risk blinded to the case or control status of participants?	NR	NR
12	Were key potential confounding variables measured and adjusted statistically in the analyses? If matching was used, did the investigators account for matching during study analysis?	NR	NR
	Quality rating	Fair	Poor

Results of Network Meta-analyses

Intervention Effects on Hamstring Tightness

Hamstring flexibility was used as the outcome measure of interest. A NMA was performed to identify the efficacy of different physical therapy interventions for hamstring tightness over control and presented in the network forest plot where a dot presented the central estimate of effect size and a line the confidence interval.

Ten comparisons against control in NMA were performed and the results of NMA are summarized in Figure 2 where the 'control' was used as the reference (Figure 2A). Since all the interventions were found to be superior to control, the second NMA was performed to identify the comparative efficacy of different physical therapy interventions for hamstring tightness over stretching (Figure 2B).

Table 5. Risk of bias assessment for pre-post studies with no control group.

Criteria Number	Criteria	Pietrzak et al., 2016	Chen et al., 2013
1	Was the study question or objective clearly stated?	Yes	Yes
2	Were eligibility/ selection criteria for the study population prespecified and clearly described?	Yes	Yes
3	Were the participants in the study representative of those who would be eligible for the test/ service/ intervention in the general or clinical population of interest?	Yes	Yes
4	Were all eligible participants that met the prespecified entry criteria enrolled?	Yes	Yes
5	Was the sample size sufficiently large to provide confidence in the findings?	NR	No
6	was the test/ service/ intervention clearly described and delivered consistently across the study population?	Yes	Yes
7	Were the outcome measures prespecified, clearly defined, valid, reliable, and assessed consistently across all study participants?	Yes	Yes
8	Were the people assessing the outcomes blinded to the participants' exposures/ interventions?	NR	NR
9	Was the loss to follow-up after baseline 20% or less? Were those lost to follow-up accounted for in the analysis?	NR	Yes
10	Did the statistical methods examine changes in outcome measures from before to after the intervention? Were statistical tests done that provided p values for the pre-to-post changes?	Yes	Yes
11	Were outcome measures of interest taken multiple times before the intervention and multiple times after the intervention (i.e., did they use an interrupted time-series design?	No	Yes
12	If the intervention was conducted at a group level (e.g., a whole hospital, a community, etc.) did the statistical analysis take into account the use of individual-level data to determine effects at the group level?	No	NR
	Quality Rating	Fair	Good

In comparison to control US guided percutaneous neuromodulation (WMD: -21.30, CI: -28.97, -13.63), dry needling (WMD: -19.65, CI: -27.48,-11.82), neurodynamic exercises (WMD: -18.29, CI:-24.45,-12.14), stretching (WMD: -13.78, CI: 16.24, -11.32), stretching combined with electrotherapy (WMD: -13.63, CI: -16.52, -10.74), massage (WMD: -12.60, CI: -19.90, -5.30) and MET (WMD: -9.77, CI: -16.83, -2.71) were statistically significantly superior to control.

US-guided percutaneous neuromodulation (WMD: -5.80, CI: -12.11, 0.51), neurodynamic exercises combined with stretching (WMD: -4.97, CI: -11.83, 1.88) presented the larger effects on hamstring flexibility although they were not statistically significantly different.

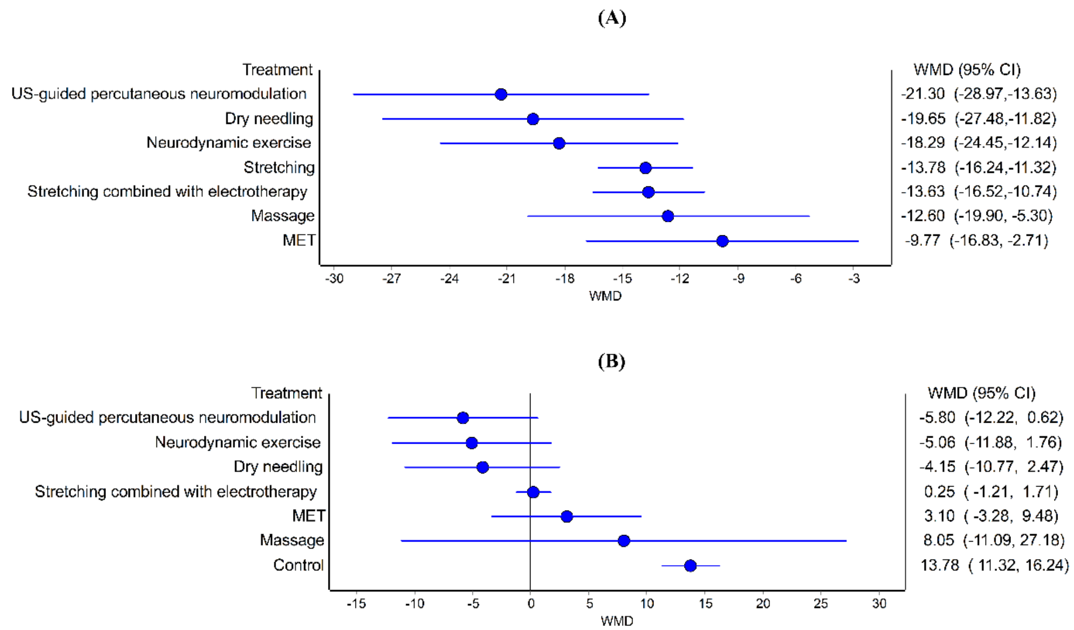

Figure 2. Forest plots of effects of different types of physical therapy interventions for hamstring tightness compared to (A) control and (B) stretching.

Stretching combined with electrotherapy i.e., cryotherapy and ultrasound (WMD: 0.25, CI: -1.14 to 1.64), MET (WMD: 3.10, CI: -3.28 to 9.48) or massage (WMD: 8.05, CI: -11.90 to 27.18) and were found inferior to stretching.

However, no intervention was found statistically significantly inferior to stretching (WMD: 13.86, CI: 11.29 to 16.42, p< 0.01).

The NMA demonstrates the following ranking of WMD for the interventions compared to control: US-guided percutaneous neuromodulation, dry needling, neurodynamic exercises combined with stretching, stretching alone, stretching combined with electrotherapy, massage, and MET. Minimal levels of inconsistency were observed with the average H-statistic being 1.19.

The impact of the interventions on hamstring flexibility improvement are summarized in Table ~~S4~~ S1 provided as a supplementary source.

Presentation of Network Structure

The NMA for hamstring tightness included seven studies and a total of 312 university students with hamstring tightness (Figure 3).

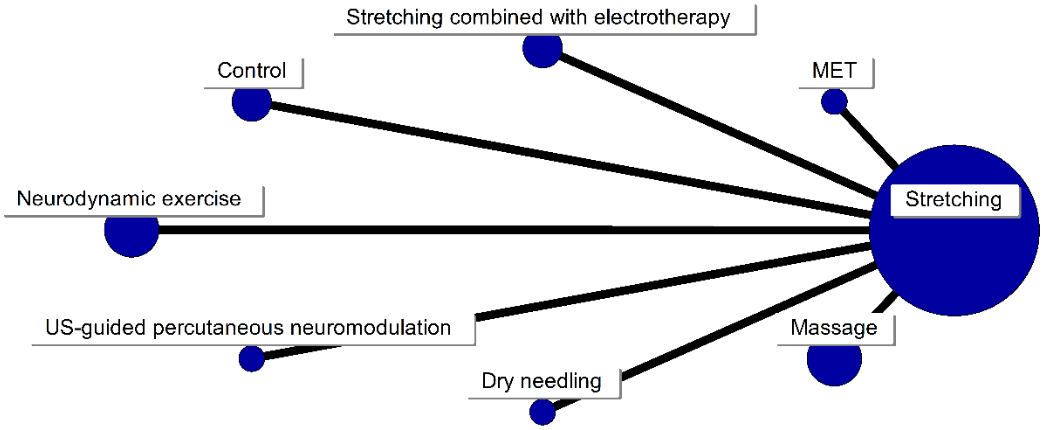

Figure 3. Network plot of physical therapy interventions for hamstring tightness.

The network diagram for the outcome of hamstring tightness contained eleven nodes, in this diagram the different interventions were denoted by nodes, while head-to-head comparisons between interventions were depicted by the edges. Line width is comparative to the number of trials. The size of the circle is considered comparative to the cumulative number of samples for each physical therapy intervention in the network.

To further investigate the efficacy of different groups of exercises over stretching, separate meta-analyses were performed.

The comparison of stretching vs control (i.e., no intervention) for hamstring tightness was carried out using the data obtained from two studies. There was low certainty evidence that stretching improved hamstring flexibility in young adults compared to no interventions (SMD 2.27, 95% 0.72 to 3.81, p < 0.01, 72 participants, I^2 =45%, Figure 4A). The overall effect was 2.88. There was a moderate heterogeneity between studies.

Further, two studies directly compared the effect of stretching on hamstring tightness compared to stretching combined with electrotherapy (i.e., cryotherapy, ultrasound) (27) or electrotherapy alone (i.e., Ultrasound) (10). Two separate comparisons were included from one study (27) as it involved a few groups to compare the effect of other forms of physical therapy interventions against stretching. There is low certainty of evidence that electrotherapy combined with stretching or electrotherapy alone make little or no difference to improve hamstring flexibility over stretching (SMD -0.07, 95% -1.00 to 0.87, p=0.88, 49 participants, I2 =47%, Figure 4B). The overall effect was 0.14. There was a moderate heterogeneity between studies.

However, it was found that stretching combined with neurodynamic exercises improves hamstring flexibility compared to stretching alone in young adults with hamstring tightness with low certainty evidence (SMD -0.69, 95% -1.35 to -0.03, p < 0.01, 87 participants, I^2 =48%, Figure 4 C). The overall effect was 2.04. The overall effect was 2.88. There was a moderate heterogeneity between studies.

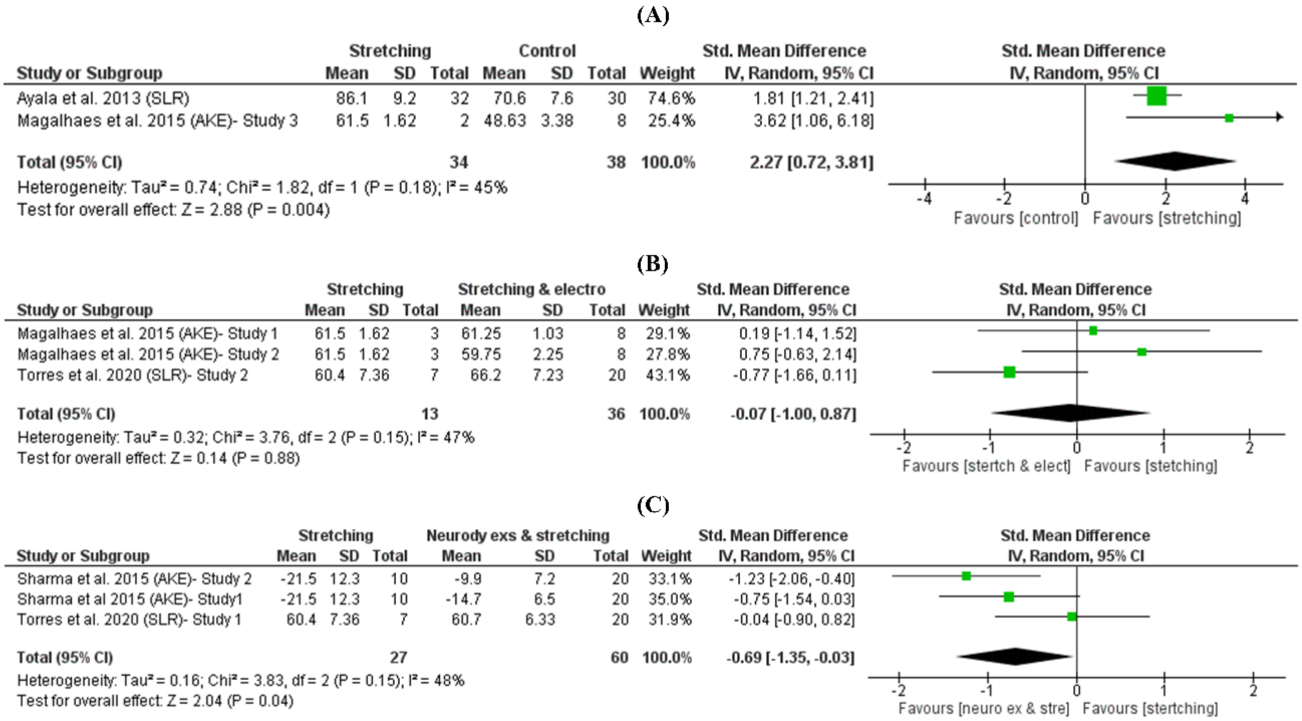

Figure 4. Forest plot of trials of stretching versus (A) no intervention, (B) electrotherapy combined with stretching and (C) neurodynamic exercises.

Descriptive Analysis of Case-Control and Pre-Post-Interventional Studies

Two case-control and two interventional pre-post studies were excluded from the network meta-analysis. Among these studies, one study assessed the effects of low intensity eccentric exercises on straight let raise and peak torque. This study concluded that the angle of peak torque occurred when the hamstring muscle was in lengthened position when low-intensity eccentric exercise was performed (31). In the other case-control study the intervention group performed dynamic stretching on the dominant leg. The findings revealed an increase in the range of movement around the knee joint (19). Of the two interventional pre-post studies, one was a counterbalanced crossover experiment (34). This study was conducted over two intervention sessions to determine the effectiveness of modified long sit slump. The findings revealed that hamstring flexibility improved on both sides among subjects with tight hamstrings (34). The other interventional study was a 1-group pre-post-test quasi-experimental design (8). The intervention was performed for three days with 7-days interval in between. The conclusion of the study was that stretching along with taping improved hamstring flexibility and the peak torque was sustained (8).

DISCUSSION

The present systematic review and network meta-analysis was carried out to evaluate the findings of studies conducted to identify the effectiveness of different physical therapy interventions in improving hamstring flexibility among university students, who were identified with hamstring tightness. The intervention methods that were used in the studies identified were: stretching, electrotherapy (cryotherapy, US guided percutaneous neuromodulation), massage (foam roller, instrument-assisted soft tissue mobilization, dry needling and neurodynamic exercises (5, 10, 24, 27, 28, 32, 39) In six RCT studies out of seven (5, 10, 27, 28, 32, 39) except one (24) stretching was used as a comparator or as an adjunct. All the interventions were compared with control by performing network meta-analysis. Also, stretching was an intervention option in most studies, all the intervention methods used in RCTs were compared with stretching through network metanalysis. Further, individual meta-analysis was performed if there were at least two studies with same treatment compared with stretching. The comparisons included: stretching vs control (no intervention), stretching vs stretching combined with electrotherapy and stretching vs stretching combined with neurodynamic exercises and neurodynamics alone.

In the first meta-analysis stretching interventions were compared with control (5), the stretching method was based on reciprocal inhibition. The mechanism of reciprocal inhibition is considered to cause automatic inhibition of antagonist which is a result of contraction of the agonist muscle group (44). The hamstring muscle was placed in maximal length to obtain maximum stretch (41). In the other study which compared stretching with control (27), the stretching exercise involved five seconds of isometric contraction soon after the muscle was relaxed. Contract-relax stretching is a form of PNF approach, which involves resisted contraction after which the body segment is stretching either actively or passively. This exercise method is considered to improve the neuromuscular response of proprioceptors, which in turn assists in increasing range of motion, improving flexibility of tight muscles and improve circulation and lymphatic drainage (1, 7). The control group in both the studies did not receive any intervention. The results revealed that the groups that performed stretching were statistically superior to control.

In the second meta-analysis stretching intervention was compared with stretching combined with electrotherapy. In one study, the subjects of each group received cryotherapy or ultrasound prior to stretching (27). The use of application is considered a cost-effective and convenient method. It reduces nerve conduction velocity, local blood flow and pain. Also, it is stated to reduce muscle guarding and thus, increase muscle flexibility. During stretching pain is considered a barrier to achieving better response, hence, application of cryotherapy prior to stretching may help in obtaining better benefits, irrespective of the duration of stretch (14, 35). Heat application is considered to increase blood flow, increase soft tissue temperature, and reduce pain leading to improved flexibility of soft tissues. Thus, application of heat prior to stretching may help in gaining greater improvements in muscle flexibility (12). In the other study passive stretching was compared with US-guided percutaneous neuromodulation. Both the studies assumed that the use of cryotherapy or heat ultrasound combined with stretching or US-guided PNM could have better effects on improving hamstring flexibility. Although, the study by De-la-Cruz-Torres and team (10), concluded that US-guided PNM had better effects than stretching, electrotherapy modalities in combination with stretching or when applied alone were not statistically superior to stretching.

In the third meta-analysis stretching was compared with neurodynamic exercises alone or neurodynamic exercises combined with stretching (10). Subjects in the neurodynamic groups performed neural sliding (10). In the other study (39), two neurodynamic exercises: neurodynamic slider (NS) and neurodynamic tensioner (NT) performed along with stretching were compared to stretching only (39). The results of the meta-analysis revealed that neurodynamic exercises when performed with stretching or neurodynamics alone were statistically superior compared to stretching alone. Adequate hamstring muscle flexibility is important for day-to-day activities, it is essential to maintain posture in standing, if tight, it leads to reduced balance, trunk stability and back injuries (37). Viscoelastic properties and stretch tolerance influence flexibility. Altered mechanosensitivity of the sciatic nerve can adversely influence stretch tolerance, causing reduced hamstring flexibility (11, 22, 40, 36). Neurodynamic exercises have been shown to improve hamstring flexibility. Among these exercises neural sliders are considered to improve excursion while neural tensioners are considered to create tension in the neural tissues (9, 25).

The subjects included in all the studies were university students identified with hamstring tightness and among the various physical therapy interventions, neurodynamic exercises combined with stretching or neurodynamics alone showed to be effective compared to all other methods. However, the level of evidence was low. Further, an important information obtained from the findings of network meta-analysis and meta-analysis is that among the different physical therapy interventions, some treatments such as dry needling, US-guided percutaneous neuromodulation, instrument assisted soft tissue mobilization require treatment from an expert and may involve an expense or cost for travel and treatment. However, none of these interventions have shown to be statistically superior to stretching alone among the university students with hamstring tightness who do not involve in competitive sports. This information may be of benefit for this vulnerable age group, and they could be managed with exercise programs that can be implemented at their dwelling and be monitored regularly to manage hamstring tightness.

Various physical therapy interventions including stretching, neurodynamic exercises, MET, US-guided percutaneous neuromodulation, dry needling, instrument assisted soft tissue mobilization and foam roller massage have shown to be superior to control i.e., no intervention. Considering comparison of all these interventions with stretching, only neurodynamic exercises combined with stretching or neurodynamic exercises alone were found to be superior to other interventions in improving hamstring flexibility among university students with hamstring tightness. Further, Quality of evidence was low; hence, further interventional studies of high-level evidence are required to ascertain the finding and to determine the superior treatment method for hamstring tightness among university students.

The present study included university students who did not participate in competitive sports, and all included participants were free of injury. Hence, the findings cannot be generalized to all the university students, who may have had a recent history of an injury or involved in competitive level sport.

Although the present network meta-analysis included seven RCTs the total sample size was only 446. The studies were downgraded because of the small sample size in GRADE assessment. Resulting in low quality of evidence. The sample size in individual studies for comparison may not be adequate to determine the effectiveness of the intervention.

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