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Review

Effectiveness of static stretching positioning on post-stroke upper-limb spasticity and mobility: Systematic review with meta-analysis

Ana Paula Salazar [a,b], Camila Pinto [a,b], Joao Victor Ruschel Mossi [c], Bruno Figueiro [c], Janice Luisa Lukrafka [a,c], Aline Souza Pagnussat [a,b,c,*]

[a] Rehabilitation Sciences Graduate Program, Universidade Federal de Ciências da Saúde de Porto Alegre, Porto Alegre, Brazil
[b] Movement Analysis and Rehabilitation Laboratory, Universidade Federal de Ciências da Saúde de Porto Alegre, Porto Alegre, Brazil
[c] Department of Physiotherapy, Universidade Federal de Ciências da Saúde de Porto Alegre, Porto Alegre, Brazil

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ABSTRACT

Objective: To systematically review the effects of static stretching with positioning orthoses or simple positioning combined or not with other therapies on upper-limb spasticity and mobility in adults after stroke.
Methods: This meta-analysis was conducted according to PRISMA guidelines and registered at PROSPERO. MEDLINE (Pubmed), Embase, Cochrane CENTRAL, Scopus and PEDro databases were searched from inception to January 2018 for articles. Two independent researchers extracted data, assessed the methodological quality and rated the quality of evidence of studies.
Results: Three studies (57 participants) were included in the spasticity meta-analysis and 7 (210 participants) in the mobility meta-analysis. Static stretching with positioning orthoses reduced wrist-flexor spasticity as compared with no therapy (mean difference [MD] = −1.89, 95% confidence interval [CI] −2.44 to −1.34; I^2 79%, $P < 0.001$). No data were available concerning the spasticity of other muscles. Static stretching with simple positioning, combined or not with other therapies, was not better than conventional physiotherapy in preventing loss of mobility of shoulder external rotation (MD = 3.50, 95% CI −3.45 to 10.45; I^2 54.7%, $P = 0.32$), shoulder flexion (MD = −1.20, 95% CI −8.95 to 6.55; I^2 0%, $P = 0.76$) or wrist extension (MD = −0.32, 95% CI −6.98 to 5.75; I^2 38.5%, $P = 0.92$). No data were available concerning the mobility of other joints.
Conclusion: This meta-analysis revealed very low-quality evidence that static stretching with positioning orthoses reduces wrist flexion spasticity after stroke as compared with no therapy. Furthermore, we found low-quality evidence that static stretching by simple positioning is not better than conventional physiotherapy for preventing loss of mobility in the shoulder and wrist. Considering the limited number of studies devoted to this issue in post-stroke survivors, further randomized clinical trials are still needed.
Clinical Trial Registration: PROSPERO (CRD42017078784).

1. Introduction

Stroke is the third leading cause of disability worldwide [1]. Cerebral stroke may result in several motor impairments including spasticity, weakness (spastic paresis) and contractures, which impose significant challenges for patient care [2]. Spasticity is one of the consequences of upper motor-neuron syndrome and is defined as a sensorimotor disorder implicated in some level of involuntary muscle activation [3,4]. Changes in mechanical muscle-fiber properties such as loss of sarcomeres and enhanced intrinsic stiffness in muscle fibers may contribute to increasing the muscle tone [5]. Spasticity limits muscle lengthening, which may have 2 consequences:

- spastic muscles have a tendency to stay in a shortened position for longer periods;
- voluntary activities of antagonist muscles are frequently restricted [6].

* Corresponding author. Universidade Federal de Ciências da Saúde de Porto Alegre, 245, Sarmento Leite Street, 90050-170 Porto Alegre RS, Brazil.
E-mail address: alinespagnussat@gmail.com (A.S. Pagnussat).

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There is an implicit assumption that spasticity results in soft-tissue changes that lead to contractures, pain, weakness, activity limitations and participation restrictions [4].

Muscle stretching is one of the physical therapy modalities most used to manage spasticity and improve the viscoelastic properties of the muscle-tendon units [7,8]. Static stretching is a widely used type of stretching and may be applied in different ways, including by physiotherapist's hands, splints, orthoses, and plaster casts [8–11]. Studies have investigated stretching therapy alone [10,12,13] or combined with other therapies [14–16] to treat spasticity [10,11,17] and increase mobility by enhancing the range of motion (ROM) [18,19] after stroke. Even though widely used, the ideal frequency, intensity, velocity, and duration of stretching therapy lacks consensus. Moreover, we do not know whether stretching programs alone or combined with other therapies are effective to reduce spasticity and/or improve joint ROM after stroke [8].

Hypertonia has both a neural and a biomechanical component that can negatively affect the quality of life of both patients and caregivers [6]. This systematic review aimed to examine the effect of static stretching therapy, combined or not with other therapies, on upper-limb spasticity and mobility of adults after stroke. The effect of static stretching with simple positioning and static stretching with positioning orthoses was investigated.

2. Methods

This systematic review and meta-analysis was performed in accordance with the Cochrane Collaboration [20] guidelines. It is presented according to the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement [21] (Appendix A). The protocol was registered at PROSPERO (http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42017078784).

2.1. Search strategy

Articles in the following electronic databases were searched from inception to April 2017: MEDLINE via PubMed, EMBASE, Cochrane Central Register of Controlled Trials (CENTRAL), Scopus, and Physiotherapy Evidence Database (PEDro). The search terms included "stroke" or "brain ischemia" and "muscle stretch exercise," and a string of words previously proposed, which yielded a high sensitivity in the search for randomized controlled trials [22], was included for the PubMed search (Appendix B). The search was limited to papers written in English, Spanish and Portuguese and the terms were adjusted to fit the requirements of each electronic database. Words relating to the outcomes of interest were not included so as to enhance the sensitivity of the search. We also searched the reference lists of the included studies to identify other relevant studies. There were no restrictions on stroke type (ischemic or hemorrhagic) or time since stroke (acute, subacute or chronic).

2.2. Selection criteria

The inclusion criteria was randomized controlled trials focused on determining the effect of static stretching combined or not with other therapies for upper-limb spasticity or mobility in adults. Studies that included participants with acute/subacute (<6 months) or chronic (>6 months) stroke were selected. Comparator groups had to receive no intervention, other therapies or conventional physiotherapy. Conventional physiotherapy was defined as usual care without specific static stretching. The exclusion criterion was no comparator. We excluded from the meta-analysis clinical trials that did not provide information on the effects of the intervention, for the experimental or control group. Authors were contacted by e-mail to obtain missing data.

2.3. Quality assessment

Two reviewers (APS and CP) independently rated the quality of studies. Disagreements in ratings were discussed until consensus was achieved or with a third reviewer (JVRM). The methodological quality and risk of bias of included studies were assessed by extracting PEDro scores from the Physiotherapy Evidence Database (www.pedroorg.au). This tool consists of 11 items, and except for item one, which pertains to external validity, each item represents one point in the total score (range = 0–10) [23]. Scores 9 or 10 are considered excellent, 6 to 8 good, 4 or 5 fair, and <4 poor. Scores 0 to 5 correspond to high risk of bias and 6 to 10 low risk of bias [24]. We used the grading of recommendation, assessment, development, and evaluation (GRADE) system to assess the quality of the body of evidence [25] as high, moderate, low or very low. The system considers susceptibility to bias, directness of evidence, heterogeneity or inconsistencies in the results, imprecision, and probability of publication bias.

2.4. Data extraction

Two reviewers (APS and CP) separately and independently evaluated the titles and abstracts of all articles identified via the search strategy. After deleting duplicates, they screened the full text of the remaining studies. The 2 investigators independently extracted data on the methodological characteristics of studies, interventions, and outcomes by using standardized forms. Interventions were detailed regarding measurement, intensity, type of activity, and frequency. The primary outcome extracted was spasticity assessed by conventional scales, including the Ashworth, modified Ashworth, and Tardieu Scales. The secondary outcome was upper-limb mobility assessed by passive ROM (PROM) trough goniometry.

2.5. Statistical analysis

For quantitative synthesis, pooled-effect estimates were obtained by comparing the change from baseline to the end of the study in each group. Regarding continuous outcomes, if the unit of measurement was consistent across studies, the results are presented as the weighted mean difference (MD) with 95% confidence intervals (95% CIs). If the unit of measurement was inconsistent, the results are expressed as the standardized mean difference (SMD) with 95% CIs. Calculations involved using the random effects method.

The statistical heterogeneity of the treatment effects among studies was assessed by the Cochran's Q and inconsistency I^2 tests. These 2 tests consider values $>25\%$ and 50% as indicating moderate and high heterogeneity, respectively. The effect size was calculated by the SMD for clinical post-treatment scores in experimental and control trials [26]. $P \leq 0.05$ was considered statistically significant. All analyses involved using R v1.0.153 (metafor package v2.0-0) [27].

3. Results

The initial electronic search identified 306 studies. After screening titles and abstracts, 20 articles were considered potentially relevant (Fig. 1). Eleven studies met the eligibility criteria, but only 10 met the criteria for the meta-analyses: 3 [10,11,13] reported data on wrist spasticity and 7 [9,12,15,18,19,28,29] reported data on

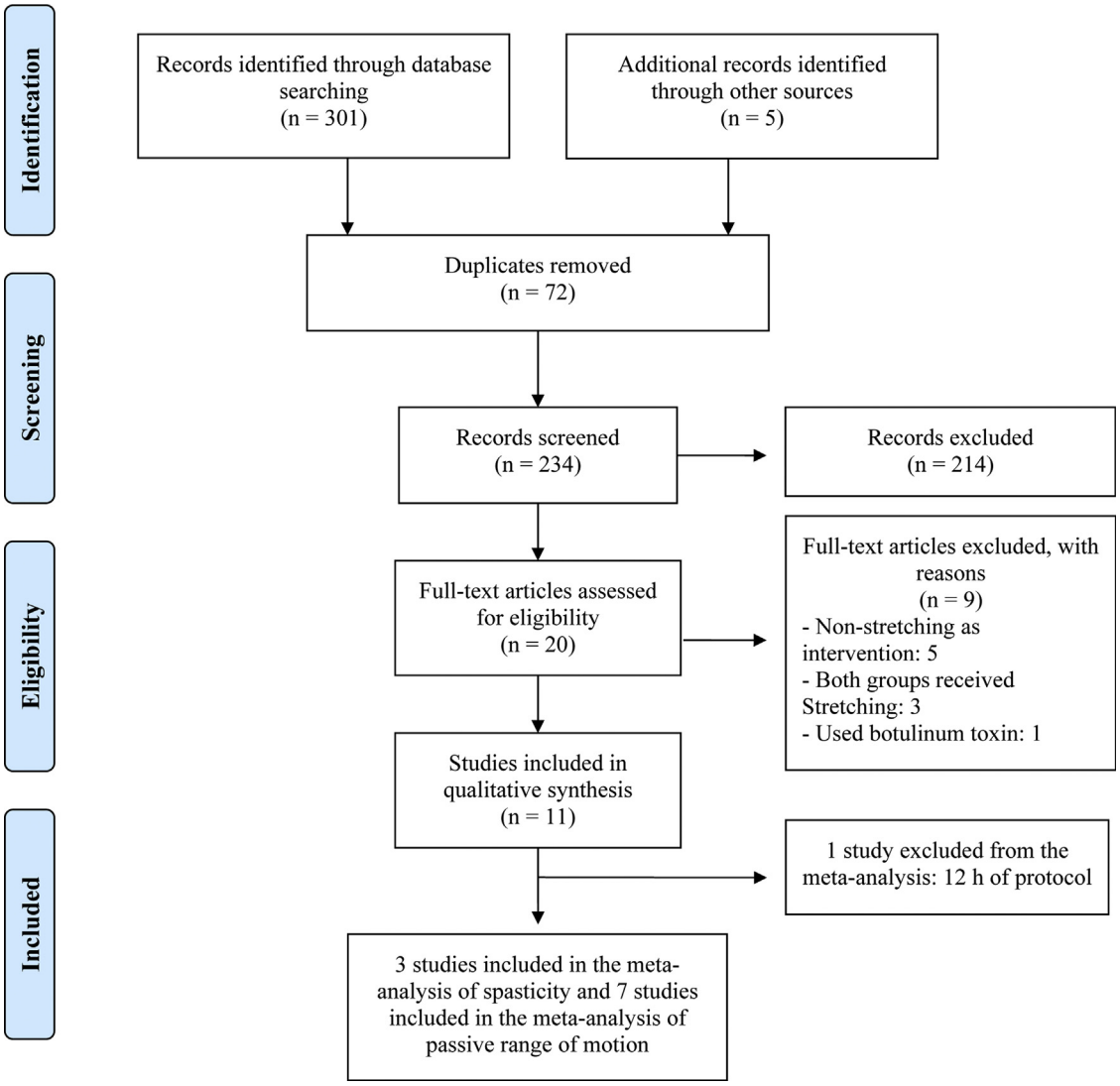

Fig. 1. The flow of studies included in the review.

upper-limb mobility after stroke. Among the 7 studies, 6 assessed shoulder external rotation PROM [9,12,15,18,19,28], 3 shoulders flexion PROM [9,12,15] and 3 wrists extension PROM [15,19,29]. One study was not included in the meta-analysis of spasticity because the protocol of the intervention was quite different (12 hr of daily stretching for 4 weeks) [30].

3.1. Participants

The mean age of participants ranged from 36 to 75.4 years (Table 1). All studies included in the wrist spasticity meta-analysis reported data for participants in the chronic phase after stroke [10,11,13]. However, studies assessing upper-limb mobility included participants with acute/subacute stroke [9,12,15,18,19,28,29]. Three studies included both ischemic and hemorrhagic stroke patients [10,18,29] and 8 did not report the type of stroke [9,11–13,15,19,28,30].

3.2. Interventions (Table 1)

Regarding the stretching protocols, meta-analyses were divided in 2 intervention types: static stretching with positioning orthoses and static stretching with simple positioning. Details on interventions are described below.

Three studies examined wrist and hand static stretching with positioning orthoses to treat spasticity [10,11,13]. These studies delivered the therapy for 6 [10,11] or 7 [13] days a week. The total time of stretching ranged from 20 [13] to 42 min [10] per day. Intervention protocols lasted from 3 [11] to 4 weeks [10,13].

Seven studies used static stretching with simple positioning [9,12,15,18,19,28,29]. These studies combined static stretching with conventional physiotherapy. This type of stretching was delivered 5 [9,12,15,28,29] or 7 [18] days a week; one study did not report this information [19]. The daily time of stretching ranged from 30 [29] to 120 min [15,19]. Intervention protocols lasted from 4 [9,29] to 8 [15,19] weeks; one study did not provide this information [18].

3.3. Quantitative data synthesis

3.3.1. Spasticity

Three studies [10,11,13] ($n = 57$ participants) assessed the effect of static stretching with positioning orthoses on wrist spasticity and were included in the meta-analysis. Static stretching alone was effective to reduce wrist flexion spasticity as compared with no therapy (MD = −1.89, 95% CI −2.44 to −1.34; I^2 79%, $P < 0.001$) (Fig. 2).

Table 1
Summary of included studies.

Study	Design	Participants	Protocol		Outcome measures
			Frequency and duration for the different groups	Characteristics	
Ada et al., 2005 [9]	RCT	$n = 36$ Age (yr) IG: 70 ± 7 CG: 64 ± 9 Sex = 13 M, 18 F Type of stroke = n/s Severity: not reported Time since stroke (month) = < 1 (acute/subacute) Follow-up: not reported	IG 60 min × 5 days/wk × 4 wk total CG 10 min × 5 days/wk × 4 wk	IG Static stretch positioning + shoulder exercises and upper-limb care CG Conventional physiotherapy with shoulder exercises without specific static stretching Muscles stretched: Internal rotators and extensors of shoulder	Passive range of motion -Goniometer Timing: 0, 4 wk
de Jong et al., 2006 [12]	RCT	$n = 19$ Age (yr) 36–63 (min–max) Sex = 9 M, 8 F Type of stroke = n/s Severity: severe Time since stroke (month) = $>3 < 6$ (subacute) Follow-up: 5 weeks	IG 60 min (30 min twice a day) × 5 days/wk × 5 wk total CG Not reported	IG Static stretch positioning + conventional physiotherapy CG Conventional physiotherapy without specific static stretching Muscles stretched: Adductors, extensors and internal rotators of shoulder; elbow flexors and forearm pronators	Spasticity Ashworth Scale Passive range of motion Hidrogoniometer Timing: 0, 5, 10 wk
de Jong et al., 2013 [15]	RCT	$n = 46$ Age (yr) IG: 56.6 ± 14.2 CG: 58.4 ± 9.6 Sex = 27 M, 19 F Type of stroke = n/s Severity: severe Time since stroke (month) = < 2 (acute/subacute) Follow-up: 12 weeks	IG 120 min (45 min twice a day) × 5 days/wk × 8 wk total CG Not reported	IG Arm static stretch positioning + NMES + conventional physiotherapy + multidisciplinary rehabilitation (rehabilitation nurses, occupational therapists and speech therapists) CG Conventional physiotherapy and multidisciplinary rehabilitation (rehabilitation nurses, occupational therapists and speech therapists) + sham arm positioning (ie, without stretching) + sham conventional TENS Muscles stretched: Internal rotators, extensors and adductors of shoulder; elbow flexors; forearm pronators; wrist flexors	Spasticity Tardieu Scale Passive range of motion Goniometer Timing: 0, 4, 8, 20 wk
Dean et al., 2000 [28]	RCT	$n = 23$ Age (yr) IG: 58.1 ± 12.5 CG: 58.2 ± 10.5 Sex = 16 M, 7 F Type of stroke = n/s Severity: not reported Time since stroke (month) = < 3 (acute/subacute) Follow-up: not reported	IG 60 min (20 min in each of 3 positions) × 5 days/wk × 6 wk total CG Not reported	IG Static prolonged stretch positioning (3 positions) + conventional physiotherapy and multidisciplinary rehabilitation (psychology, occupational therapy and social worker) CG Conventional physiotherapy without specific static stretching and multidisciplinary rehabilitation (Psychology, occupational therapy and social worker) Muscles stretched: Adductors and internal rotators of shoulder	Passive range of motion Goniometer Active range of motion Goniometer Timing: 0, 6 wk
Gustafsson and McKenna, 2006 [18]	RCT	$n = 32$ Age (yr) IG: 65.9 ± 15.6 GC: 67.1 ± 13.9 Sex = n/s Type of stroke = I/H Severity: not reported Time since stroke (month) = < 1 (acute/subacute) Follow-up: not reported	IG 40 min (20 min twice a day) of stretching × 7 days/wk (not reported weeks in total) CG 30 min × 7 days/week (not reported weeks in total)	IG Shoulder static stretch positioning + conventional daily upper-limb (affected) physiotherapy CG Conventional daily upper-limb (affected) physiotherapy without specific static stretching Muscles stretched: Internal rotators and adductors of shoulder; elbow flexors	Passive range of motion Goniometer Timing: 0 (admission), 1 (discharge)

Table 1 (*Continued*)

Study	Design	Participants	Protocol		Outcome measures
			Frequency and duration for the different groups	Characteristics	
Horsley et al., 2007 [29]	RCT	$n = 40$ Age (yr) GI: 61 ± 21 GC: 62 ± 17 Sex = 19 M, 21 F Type of stroke = I/H Severity: not reported Time since stroke (month) = < 3 (acute/subacute) Follow-up: 5 weeks	IG 30 min × 5 days/wk × 4 wk total CG 5 days/wk × 4 wk total	IG Static stretch positioning + conventional upper-limb physiotherapy CG Conventional upper-limb physiotherapy without specific static stretching Muscles stretched: Wrist and fingers flexors	Passive range of motion Goniometer Timing: 0, 4, 5, 9 wk
Jang et al., 2016 [10]	RCT	$n = 21$ Age (yr) IG: 48.8 ± 14.8 CG: 49.5 ± 14.2 Sex = 17 M, 4 F Type of stroke = I/H Severity: severe spasticity Time since stroke (month) = > 6 (chronic) Follow-up: not reported	IG 42 min (14 min in each 3 positions 3 times a day) × 6 days/wk × 4 wk total CG There was no training program	IG Wrist and hand static stretching device CG There was no training program Muscles stretched: Wrist and fingers flexors	Spasticity MAS Active range of motion Goniometer Timing: 0, 2, 4, 6 wk
Jung et al., 2011 [11]	RCT	$n = 21$ Age (yr) IG: 45.6 ± 8.1 CG: 47.5 ± 13.3 Sex = 15 M, 6 F Type of stroke = n/s Severity: severe weakness and spasticity Time since stroke (month) = > 6 (chronic) Follow-up: 1 week	IG 40 min (20 min twice a day) × 6 days/wk × 3 wk total CG There was no training program	IG Hand static stretching device (Splint) CG There was no training program Muscles stretched: Finger flexors	Spasticity MAS Timing: both groups: 6 times in 1 week; IG: 2 times before starting the stretching program
Kim et al., 2013 [13]	RCT	$n = 15$ Age (yr) IG: 47.7 ± 8.0 CG: 55.1 ± 14.0 Sex = 10 M, 5 F Type of stroke = n/s Severity: severe weakness Time since stroke (month) = > 6 (chronic) Follow-up: not reported	IG 20 min (10 min twice a day) × 7 days/week × 4 wk total CG There was no training program	IG Hand static stretching device CG There was no training program Muscles stretched: Fingers flexors	Spasticity MAS Timing: 0, 4, 8 wk
Lannin et al., 2007 [30][a]	RCT	$n = 62$ Age (yr) G1: 70.3 ± 12.6 G2: 68.7 ± 12.1 G3: 75.4 ± 11.0 Sex = 30 M, 32 F Type of stroke = n/s Severity: not reported Time since stroke (month) = < 1 (acute/subacute) Follow-up: 2 weeks	G1 (Exp) 12 hr overnight × 4 wk total G2 (Exp) 12 hr overnight × 4 wk total G3 (Con) 4 wk total	G1(Exp) Wrist static stretching device (Splint) in neutral wrist position + routine therapy G2 (Exp) Wrist static stretching device (splint) in extended wrist position plus routine therapy G3 (Con) Conventional physiotherapy without specific static stretching Muscles stretched: Wrist and fingers flexors	Spasticity Tardieu scale Passive range of motion Goniometer (assessed by lateral photographs) Timing: 0, 4, 6 wk

Table 1 (*Continued*)

Study	Design	Participants	Protocol		Outcome measures
			Frequency and duration for the different groups	Characteristics	
Turton and Britton, 2005 [19]	RCT	$n = 25$ Age (yr) IG: 66 ± 14 CG: 70 ± 10 Sex = 17 M, 8 F Type of stroke = n/s Severity: not reported Time since stroke (month) = < 1 (acute/subacute) Follow-up: 4 weeks	IG 120 min (30 min in each 2 different positions twice a day) × 8 wk total (not reported days a week) CG Not reported	IG Static stretch positioning + standard arm care without stretching CG Standard arm care without specific static stretching Muscles stretched: Shoulder adductors and internal rotators; elbow flexors; wrist flexors; finger flexors	Passive range of motion Goniometer Timing: 0, 4, 8, 12 wk

CG or Con: control group; Exp: experimental group; H: hemorrhagic; I: ischemic; IG: intervention group; MAS: Modified Ashworth Scale; n/s: no stated; RCT: randomized controlled trial; wk: week.
[a] Not included in the meta-analysis.

3.3.2. Upper-limb mobility

Six studies [9,12,15,18,19,28] ($n = 170$ participants) were included in the meta-analysis of mobility of shoulder external rotation. Static stretching with simple positioning (without any device), combined or not with other therapies, was ineffective to prevent PROM reduction in shoulder external rotation as compared with conventional physiotherapy (MD = 3.50, 95% CI −3.45 to 10.45; I^2 55%, $P = 0.32$) (Fig. 3A).

Three studies [9,12,15] ($n = 90$ participants) were included in the meta-analysis of mobility of shoulder flexion. Static stretching with simple positioning, combined or not with other therapies, was ineffective to prevent PROM reduction in shoulder flexion as compared with conventional physiotherapy (MD = −1.20, 95% CI −8.95 to 6.55; I^2 0%, $P = 0.76$) (Fig. 3B).

Finally, 3 studies [15,19,29] ($n = 105$ participants) were included in the meta-analysis of mobility of wrist extension. Static stretching with simple positioning, combined or not with other therapies, was ineffective to prevent PROM reduction in wrist extension as compared with conventional physiotherapy (MD = −0.32, 95% CI −6.39 to 5.75; I^2 38%, $P = 0.92$) (Fig. 3 C).

3.3.3. Quality of studies

The median PEDro score of included studies was 6 (range 4–9), which characterizes studies with low risk of bias (Table 2). All studies were randomized and had similar groups at baseline. Most studies reported point estimates and variability (91%), had blinded assessors (82%) and concealed the allocation list (64%). Five (45.5%) studies had adequate follow-up, used intention-to-treat analysis and reported between-group differences. Only 2 (18.2%) studies had blinded participants and no trial had blinded therapists. The quality of evidence was low for spasticity of wrist flexors by the GRADE system and was low for PROM in shoulder external rotation, shoulder flexion and wrist extension. The evidence profile is presented in Appendix C.

4. Discussion

This systematic review with meta-analysis aimed to verify the effect of static stretching therapy combined or not with other therapies on upper-limb spasticity and mobility after stroke. Our results showed that static stretching with positioning orthoses was better than no therapy for reducing spasticity of wrist flexors. Also, static stretching with simple positioning, combined with conventional physiotherapy, had similar effects as conventional physiotherapy on mobility of the shoulder (external rotation and flexion PROM) and wrist extension. To the best of our knowledge, this is the first systematic review with meta-analysis including only randomized controlled trials focused on assessing the effect of this approach on upper-limb spasticity and mobility after stroke.

Both spasticity and reduced mobility are common issues after stroke and result in decreased function due to muscle tightness of the affected extremities [13]. Static stretching is widely used as treatment after stroke and may be delivered with different approaches such as static stretching orthoses or simple positioning [13]. Our meta-analysis found very low-quality evidence for the effectiveness of static stretching with orthoses to reduce spasticity of wrist flexors as compared with no therapy. This result suggests that protocols of static stretching using hand devices in neutral or extended wrist position might be better than no therapy to reduce wrist-flexor spasticity in chronic post-stroke individuals.

All studies included in the spasticity meta-analysis examined positioning orthoses. In these studies, the duration and frequency of stretching therapy were similar [10,11,13]. These studies delivered 3 [10,13] and 4 [11] weeks of treatment. Orthoses were used 6 [10,11] and 7 [13] days per week for at least 20 min per day

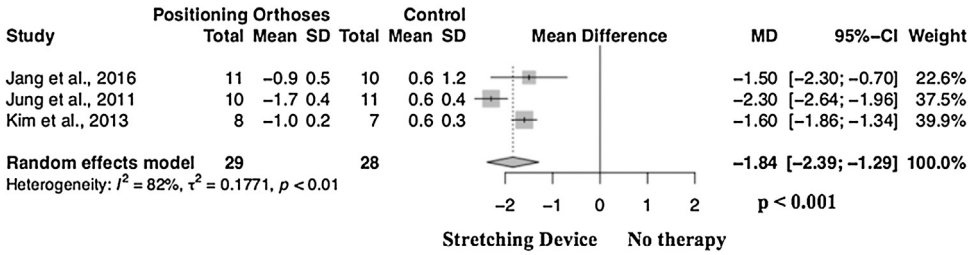

Fig. 2. Forest plot for meta-analysis of static stretching through positioning devices versus control (no therapy) on the spasticity of wrist flexors.

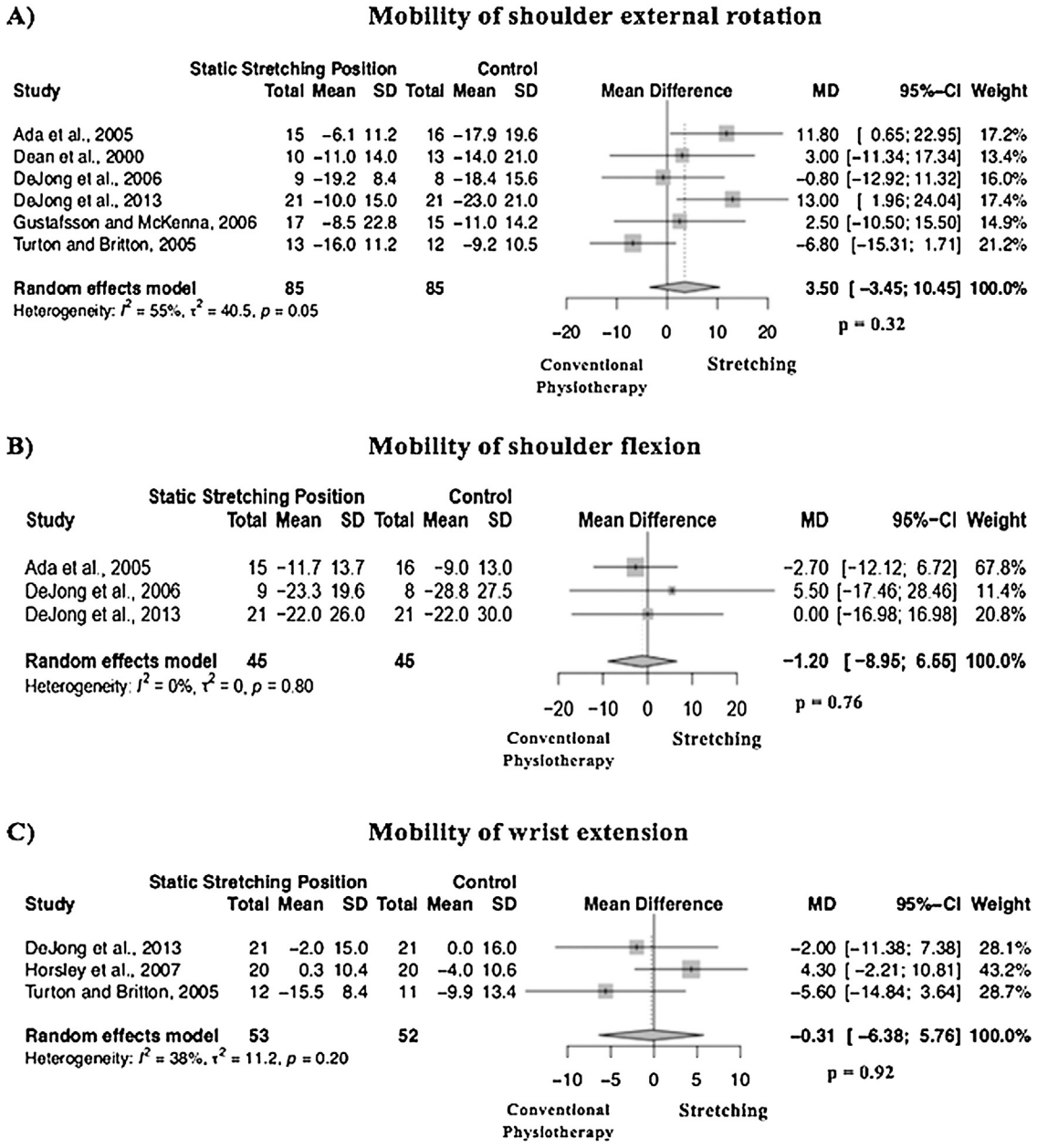

Fig. 3. Forest plot for meta-analysis of static stretching through simple positioning versus control (conventional physiotherapy without specific static stretching) on upper-limb mobility after stroke. Mobility of A) shoulder external rotation, B) shoulder flexion and C) wrist extension.

[13]. One study was excluded from the meta-analysis because it used an overnight hand device for 4 weeks [30], so the duration of stretching was very different from that in other studies. In this excluded study, the authors did not find differences in spasticity or PROM after the use of hand orthoses in neutral or extended position as compared with a control group. Regarding other muscles, no data were available on the effect of static stretching with orthoses to reduce spasticity.

Static stretching is also widely used to increase ROM after stroke [31]. Our meta-analysis showed a low quality of evidence

Table 2
PEDro scores of included studies.

Study	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	Adequate follow-up	Intention-to-treat analysis	Between-group difference reported	Point estimate and variability reported	Total score (0 to 10)
Ada et al., 2005 [9]	✓		✓			✓		✓			4
DeJong et al., 2006 [12]	✓	✓	✓			✓	✓		✓	✓	7
De Jong et al., 2013 [15]	✓	✓	✓	✓		✓	✓	✓	✓	✓	9
Dean et al., 2000 [28]	✓	✓	✓			✓		✓		✓	6
Gustafsson and McKenna, 2006 [18]	✓	✓	✓	✓		✓				✓	6
Horsley et al., 2007 [29]	✓	✓	✓			✓	✓	✓	✓	✓	7
Jang et al., 2016 [10]	✓		✓			✓				✓	4
Jung et al., 2011 [11]	✓		✓						✓	✓	4
Kim et al., 2013 [13]	✓		✓						✓	✓	4
Lannin et al., 2007 [30]	✓	✓	✓			✓	✓	✓		✓	7
Turton and Britton, 2005 [19]	✓	✓	✓			✓				✓	6
										Median (range)	6 (4–9)

that static stretching with simple positioning, combined with conventional physiotherapy, was not better than conventional physiotherapy to prevent reduced mobility of shoulder external rotation, shoulder flexion or wrist extension. No data were available on the effect of static stretching with simple positioning to prevent the loss of mobility in other upper-limb joints.

Studies included in the mobility meta-analysis examined static prolonged positioning combined with conventional physiotherapy [9,12,15,18,19,28,29] and adopted different protocols. Stretching was delivered 5 [9,12,15,28,29] or 7 [18] days a week, and the total time of stretching ranged from 30 [29] to 120 min per day [15,19]. Intervention protocols varied from 4 [9,29] to 8 [15,19] weeks. Thus, the duration and frequency of intervention were quite varied among studies. Considering the heterogeneity of studies included in our meta-analysis, it was impossible to reach conclusive results. One study [15] showed positive results of stretching in preventing loss of mobility of shoulder external rotation. However, according to the authors, these results were not clinically relevant [15] (i.e., static stretching through simple positioning did not provide benefits for participants considering the PROM of shoulder external rotation).

Regarding the maintenance of the stretching effects on spasticity, only one study found reduced hand spasticity across all times evaluated (i.e., during the stretching protocol [2 evaluations, 1 per week], immediately after the end of the protocol and 1 week post-intervention [11]). Considering the maintenance of the stretching effects on mobility, 3 studies compared static stretching positioning plus conventional physiotherapy versus conventional physiotherapy: the authors did not find any positive effect over time [15,19,29]. We did not perform a meta-analysis regarding follow-up effects because the time of follow-up was varied greatly among studies [15,19,29].

The 2 most common types of stretching are dynamic and static [32]. Dynamic stretching involves moving the body and gradually increasing the reach and/or speed of movement via functional ROM. However, static stretching means holding the stretch in maximum ROM for a certain time [32]. In our review, we included only static stretching because most studies use this type of stretching in individuals with stroke. Future studies could compare these 2 types of stretching to reduce spasticity and prevent PROM loss in people with stroke.

The studies included in this meta-analysis were similar regarding the severity of spasticity, time since stroke and duration of the stretching treatment. However, our results should be carefully interpreted because of the small number of participants included. Furthermore, the studies used a method to measure spasticity that has been questioned [33]. Although several studies focused on the reliability of the Ashworth, modified Ashworth and Tardieu Scales for the adult population [31,34], these scales have limitations that may affect their results, including anatomic and biomechanical characteristics of joints and muscle groups, inter rater and intra rater changes as well as the environment and general condition of the patient [35]. Another important limitation of this study is the significant heterogeneity presented in the spasticity meta-analysis. The high heterogeneity is probably related to the small number of participants. Previous studies also found large heterogeneity among studies, including methodology, population, intervention, and outcome measures [7,8]. Even if the included studies presented a low risk of bias, the quality of evidence was rated "very low" or "low" according to the GRADE system. Hence, we suggest further research assessing the effects of static stretching protocols to elucidate their effectiveness in both spasticity and mobility outcomes. Finally, future research should also assess the relationship between the increase in mobility (PROM) and functional recovery after stroke.

5. Conclusions

This meta-analysis revealed very low-quality evidence that static stretching with positioning orthoses is effective to diminish wrist flexor spasticity as compared with no therapy in individuals in the chronic phase after stroke. Furthermore, we found low-quality evidence that static stretching with simple positioning, combined with conventional physiotherapy, is not better than conventional physiotherapy to prevent the loss of upper-limb mobility (shoulder external rotation and flexion and wrist flexion) in individuals in the acute/subacute phase of stroke. Considering the limited number of studies devoted to this issue in post-stroke survivors, further randomized clinical trials with low risk of bias, adequate sample size and follow-up evaluation are still necessary. Future studies addressing the inconclusive elements indicated in this review may help endorse or refute the use of static stretching for improving upper-limb spasticity and mobility after stroke.

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Disclosure of interest

The authors declare that they have no competing interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.rehab.2018.11.004.

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