Shoulder strapping for stroke-related upper limb dysfunction and shoulder impairments: systematic review

*Dr Caroline Appel
St George's University of London, Clinical Sciences Department, room 6, Corridor 1
1st Floor Jenner wing, Cranmer Terrace, SW17 0RE, London
Telephone: 020 8725 5327, Mobile: 0790 521 3889, fax: -, email: cappel@sgul.ac.uk, carolinethappel@hotmail.com

Professor Lin Perry, Faculty of Health, University of Technology Sydney. G74, East Wing Edmund Blacket Building, Prince of Wales Hospital, Barker St, Randwick NSW 2031, Australia

Dr. Fiona Jones, St George's University of London and Kingston University, Faculty of Health, Social Care and Education , second floor Grosvenor Wing, Cranmer Terrace, SW17 0RE London, United Kingdom

*Corresponding author

ABSTRACT 191 words

BACKGROUND: Shoulder impairments are common after stroke, resulting in reduced upper limb function. Shoulder strapping may be beneficial as an adjunct to conventional therapy and warrants further investigation.

OBJECTIVES: To determine i) the efficacy and ii) any adverse effects of shoulder strapping used to reduce stroke-related upper limb and shoulder impairments and to improve function.

METHODS: Three reviewers independently searched CINAHL, Ovid MEDLINE, EMBASE, AMED and PEDro databases and extracted data. Results were synthesized using descriptive methods and meta-analysis and interpreted in relation to potential risk of bias.

RESULTS: Eight studies met inclusion criteria, recruiting 340 stroke participants. Studies predominantly included people with shoulder paralysis and examined shoulder strapping within four weeks of stroke onset for outcomes of increased upper limb function, reduced subluxation and pain. Strapping interventions, outcomes and measures were diverse, some studies encountered high risk of bias and findings were generally inconclusive with some indication of benefit in terms of delaying onset of shoulder pain.

CONCLUSIONS: There is insufficient evidence of efficacy or inefficacy with shoulder paralysis but shoulder strapping demonstrated minimal adverse effects and should be rigorously tested with shoulder paresis as well as paralysis after stroke.

Keywords: shoulder, stroke, strapping, upper limb, rehabilitation

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1. INTRODUCTION

In the early aftermath of stroke, shoulder strength, active range, smoothness and speed of movement has been demonstrated to reduce by a mean range of 50-74% (Canning, Ada, Adams, & O'Dwyer, 2004; Lang, Wagner, Edwards, & Dromerick, 2007; Mirbagheri & Rymer, 2008; Wagner et al., 2006). These impairments may reduce hand control, necessary for effective function of the upper limb (Beebe & Lang, 2008; Beebe & Lang, 2009). Altogether, this is likely to impede participation in high-intensity, repetitive, task-specific practice, treatments which show particular promise for improving upper limb motor recovery after stroke (Langhorne, Coupar, & Pollock, 2009). Intensive exercise might be facilitated by support for the shoulder during exercise, for example, by use of shoulder strapping.

Shoulder strapping may be applied to injured soft tissue and joints to support and protect these structures and minimise pain and swelling in the acute stages (Macdonald, 2010; Perrin, 2005). Many different strapping protocols are employed for injury prevention and rehabilitation purposes using different methods and types of strapping (Macdonald, 2010; Perrin, 2005). Criteria for good quality strapping are that it should adhere readily and maintain adhesion despite perspiration and activity (Macdonald, 2010) but rationales for choice of strapping method are unclear in stroke rehabilitation.

Shoulder strapping has been investigated predominantly in those with musculoskeletal rather than neurological disorders, where it is claimed to reduce mal-alignment of joints, scapular muscle imbalance and pain; however, further work is required to substantiate this (Cools, Witvrouw, Danneels, & Cambier, 2002; Selkowitz, Chaney, Stuckey, & Vlad, 2007; Smith, Sparkes, Busse, & Enright, 2009). One adequately powered and rigorous trial demonstrated that changing thoracic and scapular posture with strapping was associated with significant increase in active range of movement in shoulder flexion and abduction ($p < .001$) (Lewis, Wright, & Green, 2005). Shoulder strapping was considered as part of a review of supportive devices for

preventing and treating shoulder subluxation after stroke (Ada, Foongchomcheay, & Canning, 2005). Primarily focused on supportive devices such as slings, wheelchair attachments and orthoses, this review found insufficient evidence to conclude whether shoulder strapping could prevent or treat subluxation; potential to delay the onset of shoulder pain was indicated, albeit without necessarily decreasing it overall.

However, shoulder strapping is reportedly used regularly in stroke rehabilitation practice (Sandford-Smith, Morris, & Thomas, 2000). In the absence of clear direction from the literature, this is problematic. A first step in development and evaluation of shoulder strapping as a complex intervention requires conduct of a systematic review and evidence synthesis to demonstrate the basis for future developmental work (Craig et al., 2008). This was the purpose of this systematic review of shoulder strapping as an intervention after stroke.

The objectives of this systematic review were to determine i) the efficacy, and ii) any potential adverse effects of shoulder strapping used to reduce upper limb and shoulder impairments and dysfunction caused by stroke.

2. METHODS

This was a systematic review based on methods of the Cochrane Collaboration but with modified design inclusion criteria (see below) to maximise information for a topic where underpinning theory to inform choice of outcomes was lacking and high quality studies were scarce (Loke, Price, & Herxheimer, 2011; Reeves, Deeks, Higgins, & Wells, 2011).

2.1 Study selection and inclusion criteria

Search strategies were developed for the following databases: Ovid MEDLINE ® (US National Library of Medicine), EMBASE (Excerpta Medica Database), AMED (Allied and Complementary Medicine Database), CINAHL plus (Cumulative Index to Nursing & Allied Health Literature) and PEDro. Each database was searched separately with individually tailored

search terms. The search strategy addressed the topics of 'strapping', 'upper limb' and 'therapy and rehabilitation' (see Figure 1 for an example). Search strategies are available from the first author on request.

(Figure 1 about here)

Additional searches were undertaken seeking published and unpublished studies and grey literature (Figure 2).

(Figure 2 about here)

Included studies were those: i) with randomised/ quasi randomised controlled trial designs and non-randomised studies; ii) investigating the efficacy of shoulder strapping in adults with upper limb impairments and reduced upper limb function caused by stroke, iii) written in English and iv) published between January 1980 - June 2013. Non-randomised studies were defined as any quantitative study estimating the effectiveness of an intervention (beneficial or adverse) that did not use randomized allocation to comparison groups, including cohort studies, case-control studies, controlled trials and case reports (Loke et al., 2011; Reeves et al., 2011; Review Manager, 2008). Non-randomised studies were included as few randomized trials were identified, and because such studies can contribute to understand the range of effects (beneficial or adverse) of shoulder strapping that may not be adequately studied in randomized trials.

Study participants were people recruited with a stroke diagnosis.

Types of interventions were any form of strapping applied to the shoulder with therapeutic intent. Studies could include placebo strapping or no strapping as a control or comparator, but uncontrolled studies were also eligible for inclusion.

Types of outcomes were: i) participation restriction: defined as a reduced level of participation in all aspects of life; including work, family or leisure activities (World Health Organisation [WHO], 2001; WHO, 2002); ii) activity limitation outcomes: defined as difficulties an individual may have in executing activities (WHO 2001; WHO, 2002) of upper limb function; iii) impairment outcomes: defined as significant deviations or loss of bodily functions (WHO, 2001; WHO, 2002) of pain, subluxation, range of movement of the shoulder; iv) adverse events: defined as any unfavourable outcome that occurs during the intervention period and is caused by strapping products, and v) participant experience outcomes: defined as experiences of patients wearing strapping in their daily life.

The process of study selection was performed by three reviewers (CA, FJ and AC) independently using a standardized proforma. Titles were screened first, followed by abstracts and full papers. This process delivered those papers referred to as 'included studies' (Figure 2).

2.2 Quality appraisal

CA, FJ and AC assessed each included study for potential risk of bias using the Cochrane tool (Higgins, Altman, & Sterne, 2011). Items addressed selection, performance, attrition, detection, reporting and other bias and on the basis of each risk of bias study rigor was graded as adequate, unclear or inadequate.

Finally, CA, FJ and AC independently extracted data from each included study using a standardized proforma. Authors were contacted for original data if these were not included. At each step disagreements between reviewers were resolved through discussion and reference to the original paper.

2.3 Data analysis

Results were tabulated and grouped by outcome measure. For each, data were summarised with reference to the identified risk of potential bias. This descriptive synthesis was

complemented with meta-analysis of findings of randomised controlled trials, where possible, using Review Manager 5 (Review Manager, 2008). Results of randomised controlled trials and non-randomised studies were analyzed separately.

3. RESULTS

From 888 papers identified by searches eight met inclusion criteria (see website for Supplement 1: Excluded studies).

3.1 Shoulder strapping as an intervention

Six different protocols for application method and type of strapping were used (Figure 3). Strapping interventions were applied only to the gleno-humeral joint in five studies (Ancliffe, 1992; Griffin & Bernhardt, 2006; Hayner, 2012; Morin & Bravo, 1997; Pandian et al., 2013), and both the gleno-humeral joint and the scapula-thoracic joint (in part) in three studies (Appel, Mayston, & Perry, 2011; Hanger et al., 2000; Peters & Lee, 2003). Strapping interventions were developed in hospital clinical rehabilitation settings (Ancliffe, 1992; Hanger et al., 2000; Hayner, 2012) and/or were based on previous studies (Appel et al., 2011; Griffin & Bernhardt, 2006; Morin & Bravo, 1997; Pandian et al., 2013), and were founded on assumptions that shoulder strapping may:

- Reduce subluxation (Appel et al., 2011; Hanger et al., 2000; Hayner, 2012; Morin & Bravo, 1997);
- Improve joint alignment in the gleno-humeral joint and the scapula (Appel et al., 2011);
- Reduce (Hanger et al., 2000; Hayner, 2012; Pandian et al., 2013; Peters & Lee, 2003) and delay the onset pain (Ancliffe, 1992; Griffin & Bernhardt, 2006);
- Improve or maintain range of movement – active (Appel et al., 2011; Hayner, 2012; Peters & Lee, 2003), passive (Griffin & Bernhardt, 2006; Pandian et al., 2013; Peters & Lee, 2003) and pain-free movement (Hanger et al., 2000);

- Improve speed and smoothness of movement (Appel et al., 2011); and
- Prevent shoulder injuries (Pandian et al., 2013).

However, no study reported testing these suppositions in proof of principle studies to confirm underlying mechanisms.

(Figure 3 about here)

A range of different strapping products were used, applied either by the treating therapist (Griffin & Bernhardt, 2006; Hanger et al., 2000; Hayner, 2012), an alternative therapist, nurse or relative (Ancliffe, 1992; Appel et al., 2011; Pandian et al., 2013; Peters & Lee, 2003) or not stated (Morin & Bravo, 1997). Strapping was applied for durations ranging from five days (Morin & Bravo, 1997) to six weeks (Hanger et al., 2000), and re-applied every three to four days.

3.2 Study characteristics

Study characteristics are set out in Table 1. In total, 340 participants were recruited, 292 of whom participated in randomised controlled trials. Of the 160 females and 180 males, 314 were recruited within four weeks of stroke onset (Ancliffe, 1992; Appel et al., 2011; Griffin & Bernhardt, 2006; Hanger et al., 2000; Pandian et al., 2013), and 26 at up to five years after stroke onset (Hayner, 2012; Morin & Bravo, 1997; Peters & Lee, 2003). In all bar one study (Appel et al., 2011), participants presented with complete paralysis or severe shoulder weakness (Appel et al., 2011). The mean (SD) age of participants was 65 (11) years. For 33 participants, type of stroke was not reported but 242 were diagnosed with stroke caused by infarction and 65 strokes were haemorrhagic in origin (Ancliffe, 1992; Hayner, 2012; Morin & Bravo, 1997).

Five studies were classified as randomised/ quasi randomised controlled trials (Ancliffe, 1992: Appel et al., 2011; Griffin & Bernhardt, 2006; Hanger et al., 2000; Pandian et al., 2013)

and three as non-randomised studies (two case series (Hayner, 2012; Morin & Bravo, 1997), one case study (Peters & Lee, 2003)). Participation restriction outcome measures included quality of life (Stroke - Specific Quality of Life Scale (Williams, Weinberger, Harris, Biller, & Roudebush, 1999; Williams, Weinberger, Harris, Clark, & Biller, 1999)) and activities of daily life (Katz Index (Hayner, 2012)). Activity limitation outcome measures included upper limb function (Motor Assessment Scale upper limb component (Appel et al., 2011; Griffin & Bernhardt, 2006; Hanger et al., 2000)). Impairment outcomes included and were measured as follows:

- Pain severity (Visual Analogue Scale (Hanger et al., 2000; Pandian et al., 2013; Peters & Lee, 2003)), pain-free movement (shoulder lateral range of movement to the point of pain (Hanger et al., 2000)), days to onset of pain (Ritchie Articular Index (Ancliffe, 1992; Griffin & Bernhardt, 2006) and pain and disability (Shoulder Pain and Disability Index (Pandian et al., 2013));
- Subluxation (clinical and radiological assessment tools (Hanger et al., 2000; Hayner, 2012; Morin & Bravo, 1997));
- Reduced range of movement (goniometry): active (Hayner, 2012; Peters & Lee, 2003) and passive (Ancliffe, 1992; Griffin & Bernhardt, 2006; Hanger et al., 2000; Pandian et al., 2013; Peters & Lee, 2003);
- Reduced speed and dexterity (Nine Hole Peg Test, Fugl Meyer Scale - Arm section (Appel et al., 2011)).

Adverse events included skin integrity assessed through observation of skin. No data were reported in relation to participant experiences although one study (Hayner, 2012) assessed comfort of strapping (by 5-point Visual Analogue Scale).

(Table 1 about here)

No studies demonstrated adequate risk of bias (rigor) in all domains. Three non-randomised studies (Hayner, 2012; Morin & Bravo, 1997; Peters & Lee, 2003) and one quasi randomised controlled trial (Ancliffe, 1992) had three or more domains judged with inadequate rigor (Table 2).

(Table 2 about here)

3.3 Study outcomes: efficacy and adverse outcomes

Efficacy for participation and activity limitations

Shoulder strapping to reduce participation restrictions due to hemiparesis after stroke was investigated in two studies. A feasibility randomised controlled trial (Appel et al., 2011) with predominantly adequate rigor suggested a higher quality of life in the strapping group although this did not reach significance (Table 3). A non-randomised study using a single subject ABA design (Hayner, 2012) with risk of bias in one domain and unclear risk in three domains reported functional increases in activities of daily life between baseline and post intervention phases (mean scores 8.70 and 9.77, $z = -2.56$, $p = 0.01$).

(Table 3 about here)

Shoulder strapping for reduction in activity limitation of upper limb function was investigated in three randomized controlled trials (Appel et al., 2011; Griffin & Bernhardt, 2006; Hanger et al., 2000) with predominantly adequate rigor. Meta- analysis showed that the strapping group scored 0.87 points higher on the Motor Assessment Scale upper limb component (95% Confidence Interval (CI) -0.07, 1.81) compared to the control group (Appel et al., 2011; Griffin & Bernhardt, 2006; Hanger et al., 2000), which did not reach statistical significance (Table 3, Figure 4).

(Figure 4 about here)

Efficacy for pain reduction

Shoulder strapping for reduction of pain was investigated in two randomised controlled trials (Hanger et al., 2000; Pandian et al., 2013) with predominantly adequate rigor. Strapping appeared to reduce pain (assessed via Visual Analogue Scales) but this did not reach statistical significance ($p = 0.09$ (Hanger et al., 2000); $p = 0.10$ (Pandian et al., 2013), Table 3)). Data from two non-randomised studies also indicated pain reduction, but both studies encountered risk of bias - in one (Hayner, 2012) and three (Peters & Lee, 2003) domains - weakening confidence in their results.

Pain-free movement was measured using shoulder lateral range of movement to the point of pain (Hanger et al., 2000) in a trial with predominantly adequate rigor. This study reported reduced range of movement in external rotation by 15.2˚ (95% CI 10.9-19.5˚) at two weeks after stroke onset in both strapping and placebo groups. Delayed onset of pain was reported using the Ritchie Articular Index in two studies (Ancliffe, 1992; Griffin & Bernhardt, 2006), one of which (Griffin & Bernhardt, 2006) reported significantly more pain-free days for the strapping group ($F_{(31,2)} = 4.28$, $P = 0.023$, Table 3). Greater risk of bias in the older study, a quasi randomised controlled trial (Ancliffe, 1992), prohibited combination of findings in meta-analysis.

Finally, one randomised controlled trial with predominantly adequate rigor (Pandian et al., 2013) indicated better outcomes in the Shoulder Pain and Disability Index with compared to without strapping but the difference did not reach statistical significance ($p = 0.10$, Table 3).

Efficacy for reducing impairment

Shoulder strapping to reduce gleno-humeral subluxation was tested in one randomised controlled trial (Hanger et al., 2000) with predominantly adequate rigor and in two non-

randomised studies, inadequate in one (Hayner, 2012) and four (Morin & Bravo, 1997) domains. Outcome measurements completed without strapping showed no benefit (Hanger et al., 2000) whereas measurements occurring with strapping in two non-randomised studies showed benefits (Hayner, 2012; Morin & Bravo, 1997). These results should be interpreted with caution.

Shoulder strapping was assessed for effects on active and passive range of movement (ROM) in shoulder flexion/ abduction. Active ROM was examined in two non-randomised studies with inadequate rigor in one (Hayner, 2012) and three (Peters & Lee, 2003) domains. Passive ROM was examined in one non-randomised study (Peters & Lee, 2003) with inadequate rigor in three domains and two randomised controlled trials (Griffin & Bernhardt, 2006; Pandian et al., 2013) with predominantly adequate rigor. An increase in active range of shoulder flexion after shoulder strapping for three weeks was demonstrated (Hayner, 2012), from mean 37.15° to 67.84° ($z = -2.018$, $p = 0.04$). No change was seen in passive ROM (Table 3).

Shoulder strapping to improve speed and dexterity was assessed in a feasibility randomised controlled trial (Appel et al., 2011) with predominantly adequate risk of bias. Favourable results for the strapping group were suggested using the Fugl Meyer Scale - arm section, but unfavourable results using the Nine Hole Peg Test (Table 3).

Adverse events

One study included participant experience and comfort of strapping, assessed on a 5-point Visual Analogue Scale (Hayner, 2012). For nine of ten participants strapping was (very) comfortable (mean (SD) 4.4 (0.59). Overall, few adverse events were reported (Appel et al., 2011; Griffin & Bernhardt, 2006; Hanger et al., 2000; Morin & Bravo, 1997; Pandian et al., 2013). Twelve of 238 participants (5%) who received strapping experienced minor adverse events such as itching, redness of the skin or a rash; in all cases this settled after removal of strapping (Table 4).

(Table 4 about here)

4. DISCUSSION

The efficacy of shoulder strapping to alleviate upper limb dysfunction and shoulder impairments caused by stroke remains unknown. Findings were inconclusive in relation to efficacy for:

- Participation restrictions - quality of life (Appel et al., 2011) and activities of daily life (Hayner, 2012);
- Activity limitations - upper limb function (Appel et al., 2011; Griffin & Bernhardt, 2006; Hanger et al., 2000);
- Impairments – pain severity (Hanger et al., 2000; Hayner, 2012; Pandian et al., 2013), pain-free movement (Hanger et al., 2000), pain and disability (Pandian et al., 2013), gleno-humeral subluxation (Hanger et al., 2000; Hayner, 2012; Morin & Bravo, 1997) and active (Hayner, 2012; Peters & Lee, 2003) and passive (Griffin & Bernhardt, 2006; Hanger et al., 2000; Pandian et al., 2013) range of shoulder movement.

Strapping may, however, delay the onset of pain (Griffin & Bernhardt, 2006) in those with severe weakness or paralysis.

Methodological limitations included: heterogeneity of strapping methods, study outcomes, procedural use of outcome measures and inadequate study quality due to risk of bias in some studies. These precluded synthesis of results by meta-analysis other than for upper limb function. Studies were recruiting a specific subset of participants: those with complete paralysis or severe shoulder weakness, predominantly early after stroke.

However, whilst there was little evidence of benefit, neither was there clear evidence of lack of benefit. The intervention appeared well-tolerated for up to six weeks with little other than occasional minor skin irritation which settled after removal of strapping (Griffin & Bernhardt, 2006; Hanger et al., 2000; Morin & Bravo, 1997).

Studies indicate enduring interest in the use of shoulder strapping as an adjunct to rehabilitation for stroke patients (Barreca, Wolf, Fasoli, & Bohannon, 2003; Bender & McKenna, 2001; Intercollegiate Stroke Working Party, 2012; National Stroke Foundation, 2010; Page & Lockwood, 2003; Walsh, 2001), clinicians report using it (Sandford-Smith et al., 2000) and it is acknowledged in national stroke clinical guidelines. This comprehensive review demonstrated the limitations and bias of the evidence. Many studies were small in size and focused on participants with paralysis or severe paresis, who may show little improvement in upper limb function irrespective of treatment (Parry, Lincoln, & Vass, 1999). A wide variety of outcome measures were employed; lacking data demonstrating the effect size of the intervention, measures may not have been sensitive enough to detect small but clinically important change (Hanger et al., 2000; Pandian et al., 2013).

This review has highlighted major deficits in knowledge. Firstly, there appeared little consistency on what comprised strapping as an intervention after stroke. Six different protocols for application method and type of strapping were used in eight studies without a clear rationale for choice of method. Overall, there was no indication which movement impairment and what groups of participants may be most likely to benefit from each strapping procedure. Neither was there any indication of optimal dosage: strapping was applied from five days (Morin & Bravo, 1997) to six weeks (Hanger et al., 2000) without justification. Finally, it was not clear what outcomes may be most sensitive to any changes effected by strapping. Given the above points, it is clear that further work to test the effectiveness is essential.

A strength of this review was the breadth of the search strategy, with unpublished data retrieved from two (Griffin & Bernhardt, 2006; Hanger et al, 2000) but not all authors (Pandian et al., 2013). Inclusion of only English language publications was probably little limitation as only two potential non–English language papers were found. The influence of positive trial bias was probably minimal as both positive and negative outcomes were documented in included studies. Inclusion of studies using designs other than randomised controlled trials may be

regarded as a limitation, but a narrower design criterion would have prevented full exploration of this field (Greener & Langhorne, 2002; Reeves et al., 2011). Non-randomised studies were analysed separately and could not contribute findings relating to efficacy but indicated minimal adverse effects of strapping.

5. CONCLUSION

Although strapping continues to be used and referred to in the stroke literature, this review has demonstrated the inadequacy of the current evidence base. This review highlights the need for robust studies of the efficacy of shoulder strapping in people with not only severe but also mild and moderate shoulder impairments following stroke. It flags the requirement to develop and test rationales and potential working mechanisms for strapping methods. It has shown the necessity for outcome measures suitable for use in stroke patients and capable of measuring any change effected by shoulder strapping. It has identified the absence of understanding of patients' experience with shoulder strapping as an intervention. As professionals working in rehabilitation continue to use, and presumably observe benefit, from shoulder strapping in clinical practice, further research is a priority.

DECLARATION OF INTEREST

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Supplement 1: Excluded studies

Excluded studies	Reason for exclusion
Ada, L., Foongchomcheay, A., & Canning, C.G. (2005)	Systematic review, topic predominantly not relevant to this study
Alexander, C.M., Stynes, S., Thomas, A., Lewis, J. and Harrison, P.J. (2003)	Participants no diagnosis of stroke
Andeway, K. and Reynolds, J.P. (1994)	Participants no diagnosis of stroke
Clark, D. (2004)	Participants no diagnosis of stroke
Jaraczewska, E. and Long, C. (2006)	Narrative review
Kang, S.J., and Kim, I.S. (2012)	Not written in English
Kneeshaw, D. (2002)	Narrative review
Morin, G.E., Tiberio, D. And Austin, G. (1997)	Participants no diagnosis of stroke
Morrissey, D. (2000)	Narrative review
Nannetti, L., Paci, M. And Taiti, P.G. (2007)	Not written in English
Put, M. (2007)	Not written in English
Riah, L., Elmabrouki, B., Lmidmani, F., Elfatimi, A. (2011)	Conference abstract
Walker, J. (1983)	'Strapping' intervention was a sling
Zanella, P.W., Willey, S.M., Seibel, S.L. and Hughes, C.J. (2001)	Participants no diagnosis of stroke

Table 1: Characteristics of included studies

Study	Methodological quality score in 9 domains	Study design	Participants	Strapping intervention	Outcomes	
					Time points	Main measures
Ancliffe (1992)	A in 0 domains B in 2 domains C in 7 domains	Qrct	N = 8 (Exp: Con = 8: 0) Mean (SD) age: 72 (12) Stroke onset: < 48 hours	Method: ghj Period: as long as useful Type: Fixomull	Daily	RAI
Appel, et al. (2011)	A in 6 domains B in 3 domains C in 0 domains	Rct	N = 13 (Exp: Con = 6: 7) Mean (SD) age: 67.3 (9) Stroke onset: < 7 days	Methods: ghj and scj Period: 4 weeks Type: Hypafix and Strappal	0, 1, 2, 3, 5 weeks 6, 12 weeks	MAS, FMS, NHPT SS-QOL
Griffin and Bernhardt (2006)	A in 7 domains B in 2 domains C in 0 domains	Rct	N = 32 (Exp: Con: Plac = 10: 12: 10) Mean (SD) age: 62 (11) Stroke onset: < 10 days	Method: ghj Period: as long as useful Type: Fixomull	Daily 0, 4 weeks	RAI MAS, shoulder PROM with goniometer
Hanger, et al. (2000)	A in 6 domains B in 2 domains C in 1 domain	Rct	N = 98 (Exp: Con = 49: 49) Mean (SD) age: 79 (8) Stroke onset: < 4 weeks	Method: ghj/ scj Period: 6 weeks Type: Hypafix and Elastoplast Sports Strapping	0, 6, 14 weeks	SROMP, MAS, VAS
Hayner (2012)	A in 3 domains B in 5 domains C in 1 domain	Case series	N = 10 - - Stroke onset: > 1 month < 5 years	Method: ghj Period: 3 weeks Type: Mefix and Leukotape	0, 1, 2, 5 weeks	Subluxation, VAS, Katz index, shoulder AROM with goniometer, comfort of strapping
Morin and Bravo (1997)	A in 4 domains B in 1 domain C in 4 domains	Case series	N = 15 - Mean (SD) age: 65 (8) Stroke onset: < 6 months	Method: ghj Period: 5 days Type: Aerosol and adhesive bandage	0, 5, 8 days	Subluxation
Pandian, et al. (2013)	A in 8 domains B in 1 domain C in 0 domains	Rct	N = 162 (Exp: Con = 80: 82) Mean (SD) age: 57.6 (13.2) Stroke onset: < 48 hours	Method: ghj Period: 2 weeks Type: Micropore and elastic adhesive	0, 14, 30 days	VAS; SPADI; shoulder PROM with goniometer
Peters and Lee (2003)	A in 0 domains B in 6 domains C in 3 domains	Case study	N = 1 - Age: 69 Stroke onset: < 3 months	Method: ghj/ scj Period: 28 days Type: Cover-roll stretch and Leukotape	0, 28 days	Barthel Index, shoulder PROM and AROM with goniometer, VAS

A: adequate; B: unclear; C: inadequate. Qrct: quasi randomised controlled trial, Rct: randomised controlled trial; Exp: experimental; Con: control; Plac: placebo; Ghj: gleno-humeral joint; Scj: scapular joint. RAI: Ritchie Articular Index; FMS: Fugl Meyer Scale; MAS: Motor Assessment Scale; NHPT: Nine Hole Peg Test; SS-QOL: Stroke-Specific Quality of Life Scale; SROMP: shoulder lateral range of movement measured at the point of pain; VAS: Visual Analogue Scale for pain severity; SPADI: Shoulder Pain and Disability Index; PROM: passive range of movement; AROM: active range of movement.

Table 2: Risk of bias in included studies

Type of bias	Selection bias		Performance bias			Attrition bias		Detection bias	
Included Studies	Allocation concealment	Generation of allocation sequence	Difference in care	Blinding participants	Blinding providers	Protocol deviations	Analysis deviation	Assessors blinded	Selective reporting of results
Ancliffe (1992)	C	C	B	C	C	B	C	C	C
Appel, et al. (2011)	B	A	A	B	B	A	A	A	A
Griffin and Bernhardt (2006)	A	A	B	A	B	A	A	A	A
Hanger, et al. (2000)	A	A	B	C	B	A	A	A	A
Hayner, 2012	B	B	A	B	B	A	A	C	B
Morin and Bravo (1997)	C	C	B	C	C	A	A	A	A
Pandian, et al. (2013)	A	A	A	A	B	A	A	A	A
Peters and Lee (2003)	B	B	C	B	B	B	B	C	C

The grading system is: A: Adequate; B: Unclear; C: Inadequate.

Table 3: Outcomes reported in randomised/ quasi randomised controlled trial studies

Outcome	Trial	Outcome measure	Time point (weeks)	Experimental group Mean (SD)	Nr	Control group Mean (SD)	Nr	Experimental – Control group MD (95% CI)
Participation restrictions								
Quality of life	Appel, et al. (2011)	SS-QOL	13[1]-15[2]	3.44 (0.57)[1]	6	2.90 (1.38)[2]	6	0.54 (-1.287 to 2.367)
Activity limitation								
Upper limb function	Appel, et al. (2011)	MAS	3	14 (2.37)	6	12.83 (5.53)	6	1.17 (-4.30 to 6.64)
	Griffin and Bernhardt (2006)	MAS	4	1.7 (1) MAS	10	0.8 (1) MAS	12	0.9 (0 to 1.79)
	Hanger, et al. (2000)	MAS	6	4.58 (5.6)	41	3.76 (5.02)	42	0.82 (-1.5 to 3.14)
Shoulder impairments								
Pain (severity)	Hanger, et al. (2000)	VAS (cm)	6	1.7 (3)	41	2.4 (2.7)	42	-0.7 (-1.95 to 0.55)
	Pandian, et al. (2013)	VAS (cm)	4	No data reported	64	No data reported	72	-0.78 (-1.4 to 17.0)
Pain-free days	Griffin and Bernhardt (2006)	RAI	Daily	26.2 (3.9)	10	15.9 (11.6)	12	10.3 (2.27 to18.33)
	Ancliffe (1992)	RAI	Daily	21 (4.24)	4	5.5 (2.89)	4	15.5 (9.22 to 21.78)
Passive range of movement	Griffin and Bernhardt (2006)	Flexion	4	150° (26.3°)	10	145° (26.7°)	12	5° (-18.69 to 28.69)
		Abduction	4	133° (26.2°)	10	122.7° (36.6°)	12	10.3° (-18.58 to 39.18)
		External rotation	4	55° (18.4°)	10	44. 8° (15.3°)	12	10.2° (-4.77 to 25.17)
	Pandian, et al. (2013)	Flexion	4	No data reported	64	No data reported	72	No significant differences
		Abduction	4	No data reported	64	No data reported	72	No significant differences
Shoulder pain and disability	Pandian, et al. (2013)	SPADI	4	No data reported	64	No data reported	72	6.4 (-1.1 to 13.9)
Speed and dexterity	Appel, et al. (2011)	NHPT (seconds)	3	38.1 (15.8)	6	35.6 (8.3)	5	2.5 (-15.32 to 20.32)
		FMS	3	60.17 (4.22)	6	52.67 (19.14)	6	7.5 (-10.33 to 25.33)

Nr: number; SD: standard deviation; MD: mean difference; CI: confidence interval; SS-QoL: Stroke-Specific Quality of Life Scale; MAS: Motor Assessment Scale; VAS: Visual Analogue Scale; RAI: Ritchie Articular Index; SPADI: Shoulder Pain and Disability Index; NHPT: Nine Hole Peg Test; FMS: Fugl Meyer Scale.

Table 4: Adverse events

Study	Adverse events	Onset	Further information
Appel, et al. (2011)	0 of 14 developed skin reactions	No adverse events	-
Griffin and Bernhardt (2006)	1 of 20 developed skin irritation and redness (5%)	Day 1	Withdrawal from study.
Hanger, et al. (2000)	3 of 49 developed skin reactions (6%)	Day 3, 15, 39	Withdrawal from study. Skin settled quickly on removal of strapping
Morin and Bravo (1997)	2 of 19 wanted strapping removed due to itching or pain in their elbow (10%)	Not reported	Withdrawal from study.
Pandian, et al. (2013)	5 of 136 (both groups received the same strapping products) developed redness or a rash	Not reported	-

1. strapping.mp.
2. exp Bandages/
3. strapping.mp.
4. 1 or 2 or 3

5. Upper limb
6. exp Musculoskeletal System/or exp Musculoskeletal Physiologic Processes or exp Musculoskeletal Equilibrium/or exp Musculoskeletal Abnormalities/or exp Musculoskeletal Physiology/or exp Musculoskeletal Diseases/or exp Musculoskeletal Physiologic Phenomena/
7. musculoskeletal,mp.
8. exp Neurophysiology/or exp Recruitment, Neurophysiological/
9. neurophysiological,mp.
10. exp Physical Therapy Modalities/or exp Treatment Outcome/
11. physical therapy.mp.
12. exp 'Physical Therapy (Specialty)'/or exp Occupational Therapy/
13. physiotherapy.mp.
14. exercise.mp. or exp Exercise Therapy/or exp Exercise/or exp Exercise Movement Techniques/
15. exp Rehabilitation/ rehabilitation.mp.
16. 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15

17. Therapy and rehabilitation
18. exp Shoulder Joint/
19. shoulder joint.mp.

20. exp Scapula/

21. scapula.mp.

22. gleno-humeral joint.mp.

23. exp Elbow Joint/or exp Elbow/

24. elbow.mp.

25. trunk.mp.

26. torso.mp.

27. exp Upper Extremity/ upper limb.mp.

28. 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27

29. 4 and 16 and 28

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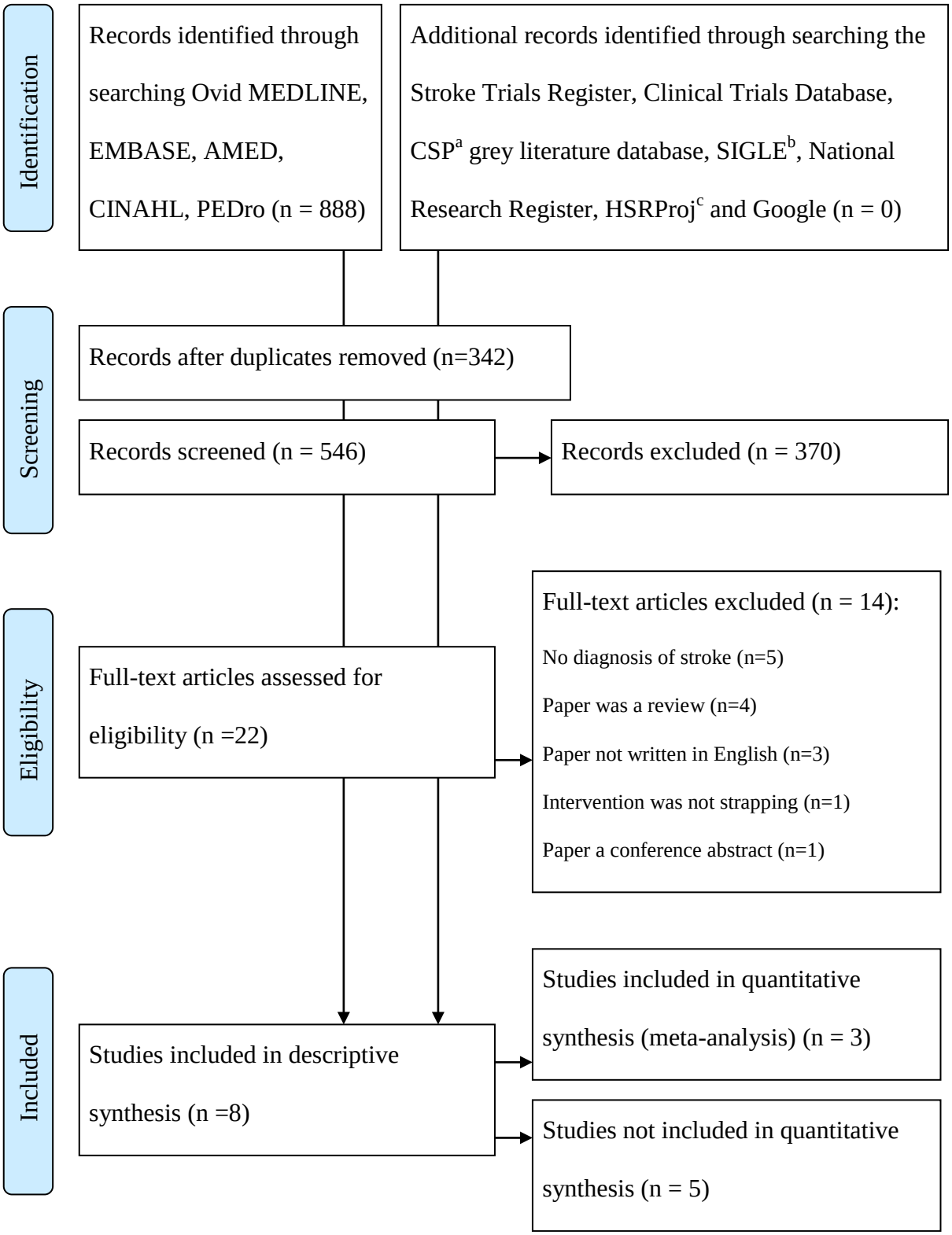
exp: explode, mp: title, original title, abstract, name of substance word, subject heading word

Figure 1: Example of a literature search in Ovid MEDLINE.



a. Chartered Society of Physiotherapists, b. System for Information on Grey Literature in Europe Archive, c. Health Services Research Projects in Progress

Figure 2: Results of the literature search.

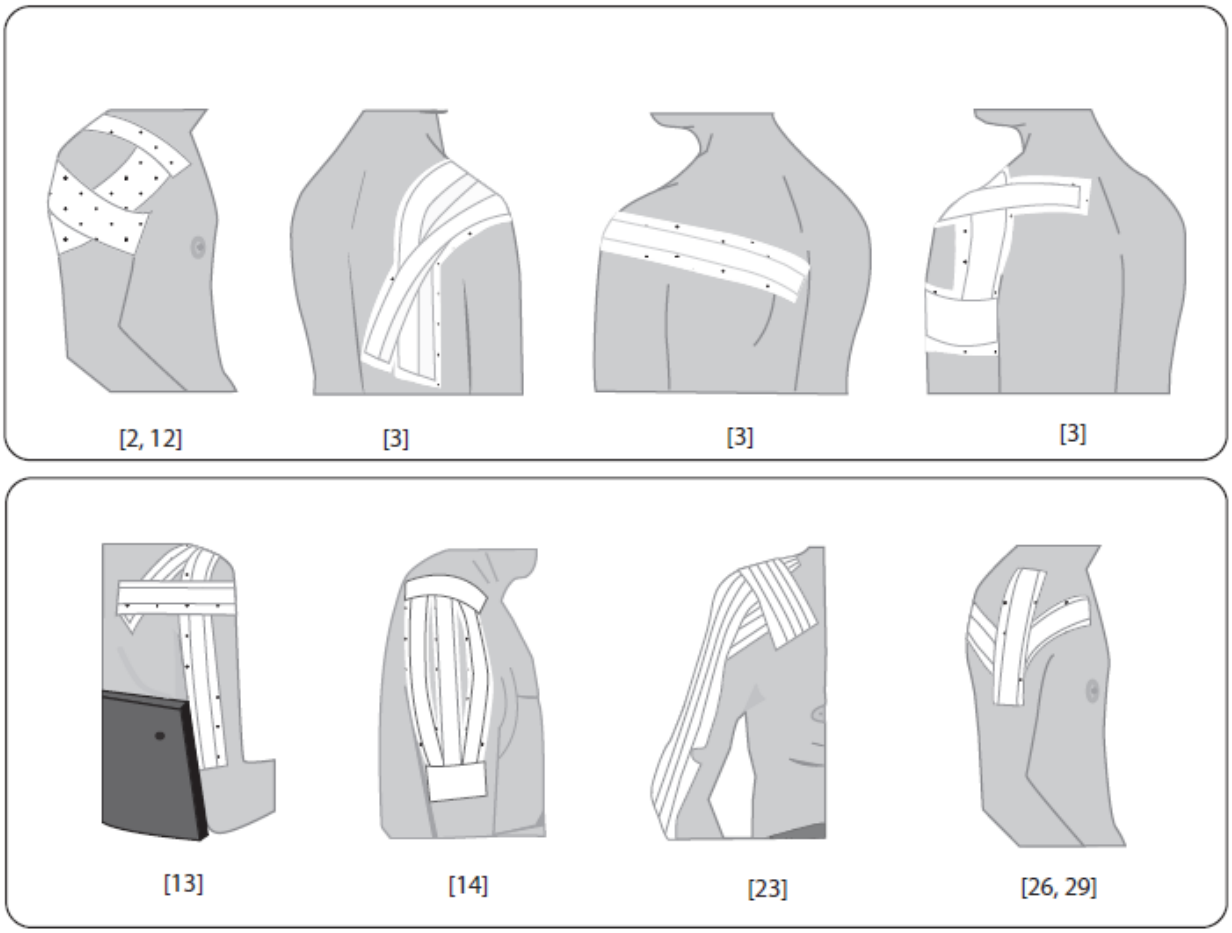


Figure 3: Six shoulder strapping protocols described in the literature.

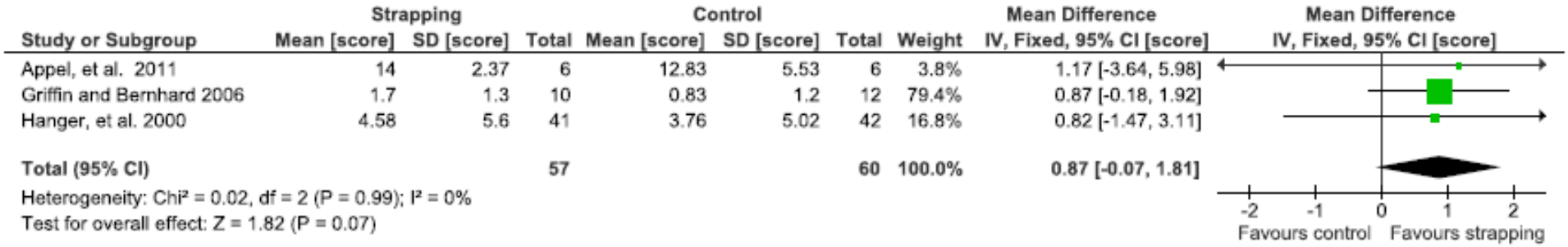


Figure 4: Meta-analysis of Motor Assessment Scale upper limb component.