Does stretching induce lasting increases in joint ROM? A systematic review

LISA HARVEY, ROBERT HERBERT and JACK CROSBIE School of Physiotherapy, University of Sydney, Australia

ABSTRACT **Background and Purpose**. *Stretching (that is, interventions that apply tension to soft tissues) induces increases in the extensibility of soft tissues, and is therefore widely administered to increase joint mobility and reverse contractures. However, it is not clear whether the effects of stretching are lasting. A systematic review was conducted to determine if stretching (either self-administered, administered manually by therapists or by some external device such as a splint) produces lasting increases in the mobility of joints not directly affected by surgery, trauma or disease processes.* **Method**. *In order to determine the lasting effects of stretching, only studies that measured joint range of motion (ROM) at least one day after the cessation of stretching were included. MEDLINE (from 1966 to June 2000), EMBASE (from 1988 to June 2000), the Cochrane Controlled Trials Register and PEDro databases were searched, and citation tracking was used to identify randomized studies that met the inclusion criteria. Each study was rated by two independent assessors on the PEDro scale, which rated trials according to criteria such as concealed allocation, blinding and intention-to-treat analysis.* **Results**. *Thirteen studies satisfied the inclusion criteria. All examined the effect of stretching (median number of stretch sessions = eight) on joint ROM in healthy subjects without functionally significant contractures. Four studies were of 'moderate' quality and the remaining nine were of 'poor' quality. The 'moderate' quality studies suggest that regular stretching increases joint ROM (mean increase in ROM = 8°; 95% CI 6° to 9°) for more than one day after cessation of stretching and possibly that the effects of stretching are greater in muscle groups with limited extensibility.* **Conclusions**. *The results of four 'moderate' quality studies show a convincing effect of stretching in people without functionally significant contracture. These findings require verification with high-quality studies. Lasting effects of intensive stretching programmes (for example, stretching applied for more than six weeks or for more than 20 minutes a day) or of stretching on people with functionally significant contracture have not yet been investigated with randomized studies.*

Key words: exercise therapy, muscles, physical therapy, stretching

INTRODUCTION

Loss of extensibility in soft tissues spanning joints restricts joint range of motion (ROM). Marked loss of joint ROM (that is, contracture) is a significant problem with diverse implications. Most importantly, contractures can impede independence (Cooper et al., 1993; Grover et al., 1996) and predispose individuals to pain and sleep disturbances (Scott and Donovan, 1981; Yarkony et al., 1985; Waring and Maynard, 1991; Dalyan et al., 1998). Even minor loss of joint ROM can have undesirable implications. For example, slight loss of passive elbow extension in C6 quadriplegic patients can impede the ability to transfer independently (Harvey and Crosbie, 1999).

Stretch interventions (that is, interventions that apply tension to soft tissues) are widely advocated as a means of inducing increases in the extensibility of soft tissues spanning joints. Consequently, these interventions are utilized to increase joint ROM and reverse contracture (St George, 1989; Krusen et al., 1990). Stretching can be self-administered or applied manually by therapists. Stretch interventions applied in these ways can normally be sustained for only a few minutes. Alternatively, stretch interventions can be applied for prolonged periods (up to 24 hours a day) with splints, plaster casts, orthoses or other devices. For example, standing paralysed patients on a tilt table is a common method of applying prolonged tension to the plantarflexor structures of the ankle.

Stretch interventions can increase the extensibility of soft tissues by two mechanisms. One mechanism involves viscous deformation and the other involves structural adaptations of muscles and other soft tissues. Viscous deformation is a mechanical response of soft tissue to sustained stretching (Bohannon, 1984; Toft et al., 1989; Magnusson et al., 1995; Magnusson et al., 1996a; Magnusson et al., 1996b). For example, Magnusson and colleagues (1996a; 1996b) and Toft et al. (1989) have shown that when the hamstrings or plantarflexor muscles are stretched to a constant angle for 90 seconds, tension in the muscles at the stretch angle declines by about 30%. This is a purely mechanical phenomenon (Herbert, 1995; Magnusson et al., 1996b) and reverses over minutes or hours upon removal of the stretch intervention. In the human plantarflexor muscles, recovery from viscous deformation occurs at a similar rate to the effects of the initial stretch intervention (Duong et al., 2001).

In contrast, increases in tissue extensibility due to structural adaptations within muscles and other soft tissues are less readily reversible. Animal studies show that days or weeks of uninterrupted stretching provided by casts can stimulate the addition of sarcomeres in series (Tabary et al., 1972). There is some evidence from animal studies to indicate that structural changes can occur in response to as little as 15 minutes of stretching a day (Williams, 1990). Addition of sarcomeres and other adaptations to prolonged stretching are presumably less readily reversed with the removal of the stretch interventions.

The purpose of the present study was to systematically review the literature to determine if stretching can induce lasting changes in joint ROM in humans. Lasting changes in joint ROM were defined as changes in joint ROM still apparent at least one day after the last stretch intervention.

This review is concerned with the effects of stretching in subjects with or without contracture, provided the joints of interest are not directly affected by trauma, surgery or disease. It will investigate only whether stretching can induce lasting change (that is, change in extensibility still evident at

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least one day after the last stretch intervention) in joint ROM, not with the underlying mechanisms. The review does not investigate the effects of stretching on clinically important end-points such as injury prevention or sports performance. Both these variables are the focus of another review currently in progress.

METHOD

Search strategy

MEDLINE (from 1966 to June 2000) and EMBASE (from 1988 to June 2000) databases were searched using phase I and II of the OVID search strategy designed by the United Kingdom Cochrane Centre (Mulrow and Oxman, 1997) to identify randomized studies. This search strategy was combined with key words specific to the topic: *muscle*, *joint*, *splint*, *contracture*, *stretch*, *range of motion*, *joint range*, *flexibility*, *stiffness*, *therapeutic exercise* and *cast*. In addition, searches were conducted of the Cochrane Controlled Trials Register (Cochrane Collaboration, 1997) and the PEDro database (Herbert et al., 1998/9). Bibliographies of relevant publications were also examined. Abstracts and unpublished material were not included. Only papers in English were reviewed.

Inclusion criteria

Papers that fulfilled the following criteria were included in the review:

- Type of study: studies in which subjects were randomly allocated to groups (Dickersin et al., 1994). The words *random*, *randomly* or *randomized* had to be used to describe treatment assignment.
- Type of intervention: studies which involved the administration of stretching with the aim of changing or preventing change in joint ROM. This included studies involving the application or administration of splints, manual stretch interventions or plaster casts, as well as studies in which stretching was self-administered by subjects. The stretching could be of any duration, frequency or intensity. To constrain the scope of the review, only studies in which stretching was administered over more than one day were included. Studies examining the effects of a single bout of stretching or a series of stretch interventions over one day were not included.
- Types of subjects: studies that involved human subjects and in which the intervention was administered to joints or tissues not directly affected by trauma, disease or surgery.
- Type of outcome measure: studies that included a measure of joint ROM, joint compliance or flexibility. Studies were only included if it was clear that measurements were made at least one day after the last stretch intervention.

Classification of studies

Potentially relevant articles were independently screened by two investigators, who later resolved disagreements by negotiation. After screening, studies were categorized into the following two groups:

- Studies which examined the effect of stretching in subjects with, or deemed susceptible to, clinically significant contractures.
- Studies which examined the effect of stretching in subjects who did not have and were not deemed susceptible to developing clinically significant contractures.

Clinically significant contractures included those that interfered with the ability to perform activities of daily living (ADL) or were associated with unsightly disfiguration. Patients were deemed susceptible to clinically significant contractures if functional use of any limb was impaired.

Assessment of trial quality

The methodological quality of included studies was scored with the PEDro scale. The PEDro scale is a checklist (details available from the authors) based on the Delphi list (Verhagen et al., 1998) and it scores trials out of ten according to the presence of ten criteria, namely use of true randomization, concealment of randomization, blinded subjects, blinded therapists, blinded assessors, appropriate statistical analysis, measures of variability and intention-to-treat analyses and the number of 'drop-outs'. The PEDro scale has been tested for reliability (Moseley et al., 1999). Observed agreement between pairs of ratings for individual scale items ranged from 69% to 96%. Pairs of raters agreed within two points on 91% of occasions. The ICC for total scores was 0.53 (95% CI 0.38–0.70), which is comparable to that of similar scales.

Two reviewers scored each trial independently, with disagreements being resolved by negotiation. Overall agreement for PEDro scores was 95% (kappa = 0.90). The quality of each study was classified as 'high', 'moderate' or 'poor' according to PEDro scores. Studies that attained a PEDro score of 7/10 or more were rated as 'high'; those with a PEDro score of 5/10 or 6/10 were rated as 'moderate' and those with a PEDro score of 4/10 or less were rated as 'poor'. This scoring system was a simplified version of that planned before the study commenced and was adopted on the recommendations of reviewers. However, the changes adopted post hoc did not substantially alter the results or conclusions of the review.

RESULTS

Thirteen studies fulfilled the selection criteria. No eligible studies examined the effect of stretching in patients with, or deemed susceptible to, clinically significant contractures.

Table 1 outlines the characteristics of the studies. Eight were published after 1990 and five were published between 1972 and 1989. None examined the effects of more than 20 minutes' stretching a day and six studies examined the effects of less than three minutes' stretching a day. One study did not provide details about the length of each stretch intervention. A median of eight treatments (range 3–56 treatments) were applied over 21 days (range 3–42 days) with a total stretching time of 30 minutes (range 3.7 minutes to 9.3 hours). No study quantified the intensity of the stretch technique applied. In seven studies subjects were selected because they had 'tight' or 'short' muscles, but in none was the tightness apparently function-limiting. All studies included a no-stretch control condition in which no alternate treatment (sham or otherwise) was applied. Only two studies (Starring et al., 1988; Magnusson et al., 1996c) utilized a within-subjects design.

Table 2 shows the PEDro score of each study. The papers are listed hierarchically, with nominally better quality papers listed first. All papers were of either 'moderate' or 'poor' quality and no study attained a PEDro score greater than 6/10 (median PEDro score = 4/10). No study explicitly concealed allocation or analysed data according to intention-to-treat and none blinded subjects or therapists. Only three

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TABLE 1: Details of studies that satisfied inclusion criteria

*Reference (quality of trial and PEDro score)**	*Subjects*	*Number of subjects***	*Mean age (SD)*	*Joint(s) or muscle(s) stretched*	*Intervention*	*Time elapsed after last stretch intervention****	*Outcome measure*	*Outcomes by group†*
Bandy et al., 1998 (moderate, 5)	Healthy subjects with 'short' hamstrings	19 19 20	26 (6)	Hamstrings	30s static stretch 30s dynamic stretch control ×5/week for 6 weeks	2 days	Passive ROM End of range determined by assessor's perception of tightness Angle measured with a goniometer	11 (7) 4 (3) 1 (2)
Bandy et al., 1997 (moderate, 5)	Healthy subjects with 'short' hamstrings	18 19 18 18 20	26 (5)	Hamstrings	3min stretch 90s stretch 60s stretch 30s stretch control ×5/week for 6 weeks	2 days	Passive ROM End of range determined by subject's perception of pain/stretch Angle measured with a goniometer	10 (8[a]) 10 (10[a]) 11 (8[a]) 12 (10[a]) 1 (8[a])
Bandy and Irion, 1994 (moderate, 5)	Healthy subjects with 'short' hamstrings	14 14 14 15	27 (5)	Hamstrings	5s stretch 30s stretch 60s stretch control ×5/week for 6 weeks	2 days	Passive ROM End of range determined by subject's perception of pain/stretch Angle measured with a goniometer	4 (7[a]) 13 (10[a]) 11 (8[a]) 0 (7[a])
Starring et al., 1988 (moderate, 5)	Healthy subjects with 'short' hamstrings	22 21 22	NA (20–40)	Hamstrings	15min cyclic stretch 15min sustained stretch control ×1/day for 5 days	7 days	Passive ROM End of range determined by assessor's perception of tightness Angle measured with a goniometer	10 (6)
McCarthy et al., 1997 (poor, 4)	Healthy	21 19	23 (2)	Neck	exercise and stretch (NA) control ×2/day for 7 days	7 days	Active ROM End of range determined by subject's perception of pain/stretch Angle measured with a cervicorometer	10[a] (15[a]) 7[a] (12[a])

Continued

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TABLE 1: continued

*Reference (quality of trial and PEDro score)**	*Subjects*	*Number of subjects***	*Mean age (SD)*	*Joint(s) or muscle(s) stretched*	*Intervention*	*Time elapsed after last stretch intervention****	*Outcome measure*	*Outcomes by group†*
Magnusson et al., 1996c (poor, 4)	Healthy	7 7	26 (6)	Hamstrings	225s of stretch control ×2/day for 20 days	1 day	Passive ROM End of range determined by torque Angle measured with Kincom	NA††
Godges et al., 1993 (poor, 4)	Healthy subjects with limited hip extension	9 7	21 (1)	Hip flexors	6min stretch control ×2/week for 3 weeks	24–48 hrs	Passive ROM End of range determined by point at which pelvis lifted Angle measured with a goniometer	11[a] (6[a]) –2[a] (9[a])
Lentell et al., 1992 (poor, 4)	Healthy	18 16	24 (4)	Shoulders	15min stretch control ×3 over 5 days	3–7 days	Passive ROM End of range determined by gravity	2 (7) 0 (4)
Bohannon, 1984 (poor, 4)	Healthy	10 10	24[a] (4[a])	Hamstrings	8min stretch control 3 over 5 days ×1/day for 3 days	1 day	Passive ROM End of range determined by torque Angle measured with video	4[a] (11[a]) 1[a] (9[a])
Halbertsma and Goeken 1994 (poor, 3)	Healthy subjects with 'short' hamstrings	9 9	27 (5[a])	Hamstrings	10min stretch control ×2/day for 4 weeks	>12 hrs	Passive ROM End of range determined by onset of EMG Angle measured with an electrogoniometer	5 (6) 1 (2)
Hardy, 1985 (poor, 3)	Healthy	7 7 7 7 7 7 7	NA (18–22)	Hip	90s stretch 90s stretch 90s stretch 90s stretch 90s stretch 90s stretch control ×1/day for 6 days	1 day	Active ROM End of range determined by subject's perception of pain/stretch Angle measured with flexometer	5 (4) 13 (7) 14 (8) 11 (4) 7 (11) 8 (7) 0 (3)

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Mederios et al., 1977 (poor, 3)	Healthy	10 10	26 (21–34)	Hamstrings	1min stretch control ×1/day for 8 days	24 hours	Passive ROM End of range determined by torque Angle measured with a goniometer	6 (4) 1 (2)
Tanigawa, 1972 (poor, 3)	Healthy subjects with 'short' hamstrings	10 10	NA (20–48)	Hamstrings	< 1min hold–relax procedure 15s static stretch control ×2/week for 3 weeks	1 week	Passive ROM End of range determined by subject's perception of pain/stretch Angle reflected from distance between ankle and ground	10[a] (NA) 2[a] (NA) 0[a] (NA)

ROM = range of motion.
NA indicates that insufficient data were available.
[a] indicates data were derived from data presented in the paper.
* See Table 2 for details of quality of trial and PEDro scores.
** Number of subjects allocated to each group. Number of subjects are reported for each group in the order that the interventions are presented in the intervention column. All meta-analyses were based on number of subjects that completed the study.
*** Time between the last treatment and re-assessment.
† The size of the treatment effect is reported as the mean (±SD) change in joint ROM for the different interventions (a positive value indicates an increase in ROM). In some cases the mean and SD of the change score were calculated from the means and SDs of pre-test and post-test as recommended by the Cochrane Collaboration (Mulrow and Oxman, 1997). When identical interventions were applied to right and left legs the mean result is reported. Outcomes are reported for each group in the order that the interventions are presented in the intervention column.
†† This paper measured outcomes in terms of stiffness and torque at a target angle. Data were only presented graphically.

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studies used blinded assessors. All studies utilized random allocation (this was an inclusion criteria) and all but one study performed between-group statistical comparisons and provided point measures and measures of variability.

The data from the four 'moderate' quality studies were subjected to meta-analysis (Figure 1). Weighted mean differences between groups were obtained by weighting differences between groups in each study according to the inverse of the variances of their estimates (Armitage and Berry 1994). A visual inspection of the data in Figure 1 suggested homogeneity of effect, so a fixed-effects model was used. The mean increase in ROM was 8˚ (95% CI 6˚ to 9˚). Analysis with a random effects model made no difference to results (NHS Centre for Reviews and Dissemination, 1996). An equivalent meta-analysis was performed including the 'poor' quality trials using a random effects model. The mean increase in ROM was 6˚ (95% CI 5˚ to 8˚), indicating that the 'poor' quality trials did not bias results appreciably.

Post hoc meta-analyses were performed to explore the possibility that the size of the treatment effect was dependent on duration of treatment (less than three weeks' treatment was compared with more than three weeks' treatment) or pre-existing joint ROM (treatments applied to muscles with limited extensibility was compared to treatments applied to muscles with 'normal' extensibility). There were too few papers to examine the effect of stretching on different joints and muscle groups. Eleven of the 13 studies were included in these post hoc analyses. Two studies (Tanigawa, 1972; Magnusson et al., 1996c) were excluded from analyses because joint ROM measures were not provided. Treatments applied over more than three weeks (mean increase in ROM = 8˚; 95% CI 6˚ to 10˚) and treatments applied to muscles with limited extensibility (mean increase in ROM = 8˚; 95% CI 6˚ to 9˚) were marginally more effective than treatment applied over less than three weeks (mean increase in ROM = 5˚; 95% CI 3˚ to 8˚) and treatments applied to muscles of 'normal' extensibility (mean increase in ROM = 4˚; 95% CI 2˚ to 7˚).

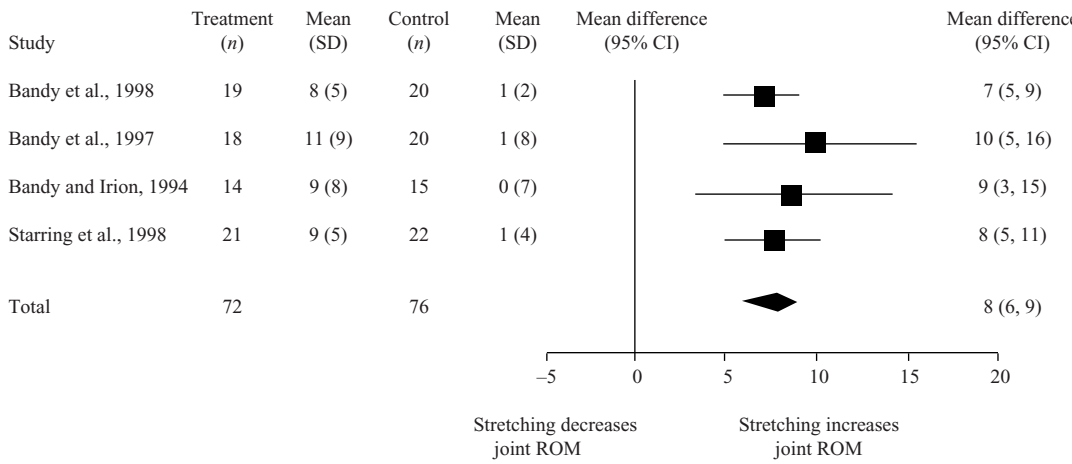

FIGURE 1: Results of meta-analysis. Only studies of 'moderate' quality were included. Point estimates have been rounded to the nearest integer.

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TABLE 2: Quality ratings of studies that satisfied inclusion criteria (see text for details)

	PEDro scale										*Score*	
Source	*Random*	*Allocation concealed*	*Baselines similar*	*Subjects blind*	*Therapist blind*	*Assessor blind*	*< 15% drop-out*	*Intention to-treat*	*Statistical analysis*	*Point measures*	*PEDro score*	*Quality*
Bandy et al., 1998	y	n	y	n	n	y	n	n	y	y	5	Moderate
Bandy et al., 1997	y	n	y	n	n	n	y	n	y	y	5	Moderate
Bandy and Irion, 1994	y	n	y	n	n	y	n	n	y	y	5	Moderate
Starring et al., 1998	y*	n	y	n	n	n	y	n	y	y	5	Moderate
McCarthy et al., 1997	y	n	n	n	n	y	n	n	y	y	4	Poor
Magnusson et al., 1996c	y	n	y	n	n	n	n	n	y	y	4	Poor
Godges et al., 1993	y	n	y	n	n	n	n	n	y	y	4	Poor
Lentell et al., 1992	y	n	y	n	n	n	n	n	y	y	4	Poor
Bohannon, 1984	y	n	y	n	n	n	n	n	y	y	4	Poor
Halbertsma and Goeken, 1994	y	n	y	n	n	n	n	n	n	y	3	Poor
Hardy, 1985	y	n	n	n	n	n	n	n	y	y	3	Poor
Mederios et al., 1977	y	n	n	n	n	n	n	n	y	y	3	Poor
Tanigawa, 1972	y	n	y	n	n	n	n	n	y	n	3	Poor

* Subjects were randomly allocated to the two treatment groups but not to the control group.

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DISCUSSION

Physiotherapists often apply stretch interventions to people whose tissues are not directly affected by disease, surgery or trauma. Despite the widespread use of these interventions, surprisingly few studies, and none of 'high' quality, have examined the lasting effects of stretching in this population and no study has examined the effect of stretching on patients with, or at risk of, clinically significant contracture. Good evidence about the lasting effects of stretching in these groups is needed urgently. In addition, well designed studies are needed to determine how quickly the benefits of stretching are lost with the cessation of treatment, and the effectiveness of more aggressive stretch interventions (that is, the effectiveness of stretch interventions applied for longer periods of time and with larger torques).

This systematic review indicates that stretching administered over more than one day to healthy tissues not directly affected by disease, trauma or surgery and without pre-existing contracture, increases joint ROM by 8°. This result should be interpreted with caution because no study was of 'high' quality and it is possible that both 'moderate' and 'poor' quality studies exaggerate the real size of the treatment effect. In addition, caution is warranted because of the inherent difficulties associated with pooling results of studies that employ a range of stretching interventions applied at different dosages to different soft tissues.

There is some suggestion that stretching applied for more than three weeks and stretching applied to muscles with limited extensibility may be more effective than stretching applied for less than three weeks and to muscles with 'normal' extensibility. These findings are based on between-study comparisons and post hoc analyses, and therefore should only be used to indicate areas worthy of further investigation.

Limitations of the review

It is possible that key studies which fulfilled the inclusion criterian were either missed or not retrieved. Studies may have been missed if they were from journals not included in the databases searched or if they used obscure key words (Egger et al., 1997; Egger and Smith, 1998). To minimize these problems, a diverse range of key words was included in the search strategy and many sources were searched, including the bibliographies of included and excluded studies. Some studies may not have been retrieved if their abstracts were misleading or uninformative, although efforts were made to retrieve full papers whenever their suitability was unclear.

The resources were not available to interpret papers in foreign languages or to retrieve unpublished papers. It is possible that papers in languages other than English were omitted and that unpublished findings have been ignored. It is estimated that 25–50% of clinical trials are not published (Dickersin et al., 1994). Trials that do not show significant treatment effects may be less likely to be published in English language journals (Egger and Smith, 1998). Consequently, reviews may be subject to publication bias. In the present review, there were too few studies to enable the use of methods to detect publication bias (such as so-called 'funnel plots'; NHS Centre for Reviews and Dissemination, 1996).

PEDro scores were used to define the quality of studies based on well-accepted standards of clinical trials. Although there are many advantages of the PEDro scale, it does not distinguish between studies that clearly do not satisfy criteria and those which may have satisfied criteria but failed to pro-

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vide sufficient information about the details of their methodology, nor does it weight criteria according to their importance.

Methodological quality

Therapists and subjects were never blinded. Clearly, this is difficult (though sometimes not impossible) to achieve in studies of the effect of stretching. Perhaps on these grounds, the criteria dealing with the subject and therapist blinding should have been omitted from the PEDro scale and trials scored out of eight rather than ten. This approach was not adopted because failure to blind therapists, and particularly subjects, remains a potential source of bias and needs to be accounted for when evaluating the effectiveness of stretch interventions. It is difficult to explain why so few studies blinded assessors.

The degree of biasing introduced by the use of non-blinded subjects and assessors can be minimized with appropriate methodology. For example, bias due to the use of non-blinded assessors can be reduced with torque-controlled joint ROM measures. In the same way, bias introduced by the use of non-blinded subjects can be minimized if passive, rather than active joint ROM measures are used. Increases in joint ROM in non-blinded subjects do not necessarily indicate a change in the extensibility of soft tissues. Rather, an increase in ROM may reflect a change in a subject's willingness to generate a stretch torque (in the case of active ROM) or a change in a subject's tolerance to stretching (in the case of passive ROM; Magnusson et al., 1996c; Magnusson, 1998). At the onset of this review it was intended to rate studies that failed to blind subjects and assessors on the basis of their methodology. However, on the advice of reviewers and for the sake of simplicity, this rating system was subsequently dropped. The results and conclusions of the review were not substantially affected by this post hoc change.

CONCLUSION

There is evidence to suggest that stretching produces increases in joint ROM that are still evident one or more days after cessation of treatment in people without clinically significant contractures. These results should be interpreted with caution until verified with high-quality studies. Studies are required to determine the effects of stretching on people with functionally significant contracture, the effects of longer periods of stretching (that is, stretching applied for more than 20 minutes a day or over more than six weeks) and the sustained effects of stretching (that is, effects evident more than one week after the cessation of stretching).

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REFERENCES

Armitage P, Berry G. Statistical Methods in Medical Research. Oxford: Blackwell Science, 1994.

Bandy WD, Irion JM. The effect of time on static stretch on the flexibility of the hamstring muscles. Physical Therapy 1994; 74: 845–850.

Bandy WD, Irion JM, Briggler M. The effect of time and frequency of static stretching on flexibility of the hamstring muscles. Physical Therapy 1997; 77: 1090–1096.

Bandy WD, Irion JM, Briggler M. The effect of static stretch and dynamic range of motion training on the flexibility of the hamstring muscles. Journal of Orthopaedic and Sports Physical Therapy 1998; 27: 295–300.

Bohannon RW. Effect of repeated eight-minute muscle loading on the angle of straight-leg raising. Physical Therapy 1984; 64: 491–496.

Cochrane Collaboration. Cochrane Library, CD-ROM and online. Cochrane Collaboration (issue 1). Oxford: Update Software, 1997.

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Cooper JE, Shwedyk E, Quanbury A, Miller J, Hildebrand D. Elbow joint restriction: effect on functional upper limb motion during performance of three feeding activities. Archives of Physical Medicine and Rehabilitation 1993; 74: 805–809.

Dalyan M, Sherman A, Cardenas DD. Factors associated with contractures in acute spinal cord injury. Spinal Cord 1998; 36: 405–408.

Dickersin K, Scherer R, Lefebvre C. Identifying relevant studies for systematic reviews. British Medical Journal 1994; 309: 1286–1291.

Duong B, Low M, Moseley AM, Lee RY, Herbert RD. Time course of stress relaxation and recovery in human ankles. Clinical Biomechanics 2001; 16: 601–607.

Egger M, Smith GD. Meta-analysis. Bias in location and selection of studies. British Medical Journal 1998; 316: 61–66.

Egger M, Smith GD, Phillips AN. Meta-analysis. Principles and procedures. British Medical Journal 1997; 315: 1533–1537.

Godges JJ, MacRae PG, Engelke KA. Effects of exercise on hip ROM, trunk muscle performance, and gait economy. Physical Therapy 1993; 73: 468–477.

Grover J, Gellman H, Waters RL. The effect of a flexion contracture of the elbow on the ability to transfer in patients who have quadriplegia at the sixth cervical level. Journal of Bone Joint Surgery (American volume) 1996; 78: 1397–1400.

Halbertsma JP, Goeken LN. Stretching exercises: effect on passive extensibility and stiffness in short hamstrings of healthy subjects. Archives of Physical Medicine and Rehabilitation 1994; 75: 976–981.

Hardy L. Improving active range of hip flexion. Research Quarterly 1985; 56: 111–114.

Harvey LA, Crosbie J. Weight bearing through flexed upper limbs in tetraplegics with paralyzed triceps brachii muscles. Spinal Cord 1999; 37: 780–785.

Herbert R. Adaptations of muscle and connective tissue. In: Gass E, Refshauge K (eds). Musculoskeletal Physiotherapy: Clinical Science and Practice. London: Butterworth-Heinemann, 1995; 27–32.

Herbert R, Moseley A, Sherrington C. PEDro: a database of randomized controlled trials in physiotherapy. Health Information Management 1998/9; 28: 186–188.

Krusen FH, Kottke FJ, Lehmann JF. Handbook of Physical Medicine and Rehabilitation. Philadelphia: Saunders, 1990.

Lentell G, Hetherington T, Eagan J, Morgan M. The use of thermal agents to influence the effectiveness of a low-load prolonged stretch. Journal of Orthopaedic and Sports Physical Therapy 1992; 16: 200–207.

Magnusson SP. Passive properties of human skeletal muscle during stretch maneuvers. A review. Scandinavian Journal of Medicine and Science in Sports 1998; 8: 65–77.

Magnusson SP, Simonsen EB, Aagard P, Gleim GW, McHugh MP, Kjaer M. Viscoelastic response to repeated static stretching in the human hamstring muscle. Scandinavian Journal of Medicine and Science in Sports 1995; 5: 342–347.

Magnusson SP, Simonsen EB, Aagard P, Gleim GW, Kjaer M. Biomechanical responses to repeated stretches in human hamstring muscle *in vivo*. American Journal of Sports Medicine 1996a; 24: 622–628.

Magnusson SP, Simonsen EB, Dhyre-Poulsen, Aagard P, Mohr T, Kyaer M. Viscoelastic stress relaxation during static stretch in human skeletal muscle in the absence of EMG activity. Scandinavian Journal of Medicine and Science in Sports 1996b; 6: 323–328.

Magnusson SP, Simonse EB, Aagaard P, Sorense H, Kjaer M. A mechanism for altered flexibility in human skeletal muscle. Journal of Applied Physiology 1996c; 497: 291–298.

McCarthy PW, Olsen JP, Smeby IH. Effects of contract–relax stretching procedures on active range of motion of the cervical spine in the transverse plane. Clinical Biomechanics 1997; 12: 136–138.

Medeiros JM, Smidt GL, Burmeister LF, Soderberg GL. The influence of isometric exercise and passive stretch on hip joint motion. Physical Therapy 1977; 57: 518–523.

Moseley AM, Maher C, Herbert RD, Sherrington C. Reliability of a scale for measuring the methodological quality of clinical trials. In: Proceedings of the VIIth Cochrane Colloquium. Rome, 1999; 39.

Mulrow CD, Oxman AD. Cochrane Collaboration Handbook (updated September 1977). In: The Cochrane Library (database on disk and CD-ROM). Oxford. Update Software. The Cochrane Collaboration, 1997.

NHS Centre for Reviews and Dissemination. Undertaking Systematic Reviews of Research Effectiveness. CRD guidelines for those carrying out or commissioning reviews. CRD Report Number 4, 1996.

Scott JA, Donovan WH. The prevention of shoulder pain and contracture in the acute tetraplegia patient. Paraplegia 1981; 19: 313–319.

St George F. The Muscle Fitness Book. Sydney: Simon and Schuster, 1989.

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Starring DT, Gossman MR, Nicholson GG, Lemons J. Comparison of cyclic and sustained passive stretching using a mechanical device to increase resting length of hamstring muscles. Physical Therapy 1988; 68: 314–320.

Tabary JC, Tabary C, Tardieu C, Tardieu J-C, Goldspink G. Physiological and structural changes in the cat's soleus muscle due to immobilization at different lengths by plaster casts. Journal of Physiology 1972; 224: 231–244.

Tanigawa M. Comparison of the hold–relax procedure and passive mobilization on increasing muscle length. Physical Therapy 1972; 52: 725–734.

Toft E, Esperson GT, Kalund S, Sinkjaer T, Hornemann BC. Passive tension of the ankle before and after stretching. American Journal of Sports Medicine 1989; 17: 489–494.

Verhagen AP, de Vet HC, de Bie RA, Kessels AG, Boers M, Bouter LM et al. The Delphi list: a criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi consensus. Journal of Clinical Epidemiology 1998; 51: 1235–1241.

Waring WP, Maynard FM. Shoulder pain in acute traumatic quadriplegia. Paraplegia 1991; 29: 37–42.

Williams PE. Use of intermittent stretch in the prevention of serial sarcomere loss in immobilised muscle. Annals of the Rheumatic Diseases 1990; 49: 316–317.

Yarkony GM, Bass LM, Keenan V, Meyer PR. Contractures complicating spinal cord injury: incidence and comparison between spinal cord centre and general hospital acute care. Paraplegia 1985; 23: 265–271.

Address for correspondence: Dr Lisa Harvey, Department of Physiotherapy, Moorong Spinal Unit, Royal Ryde Rehabilitation Centre, 600 Victoria Road, Ryde, NSW 2112, Australia (E-mail: harveyl@doh.health.nsw.gov.au).

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