



Effects of stretching before and after exercising on muscle soreness and risk of injury: systematic review

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What is already known on this topic

Radiotherapy is commonly given to patients with inoperable non-small cell lung cancer in the United Kingdom

One or two fractions of palliative radiotherapy can control thoracic symptoms

What this study adds

In the group of patients with no symptoms or only minimal symptoms, palliative thoracic radiotherapy can be safely deferred until significant thoracic symptoms appear

Compared with immediate, palliative radiotherapy, no evidence exists that such a policy affects patients' survival or levels of activity, anxiety, or depression

cal Research Council Lung Cancer Working Party.

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Contributors: see bmj.com

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Competing interests: None declared.

- 1 Medical Research Council Lung Cancer Working Party. Randomised trial of palliative two-fraction versus more intensive 13-fraction radiotherapy for patients with inoperable non-small cell lung cancer and good performance status. *Clin Oncol* 1996;8:167-75.
- 2 World Health Organization. WHO handbook for reporting results of cancer treatment. WHO Offset Publication No. 48. Geneva: WHO, 1979.
- 3 Medical Research Council Lung Cancer Working Party. Inoperable non-small-cell lung cancer (NSCLC): a Medical Research Council randomised trial of palliative radiotherapy with two fractions or ten fractions. *Br J Cancer* 1991;63:265-70.
- 4 Medical Research Council Lung Cancer Working Party. A Medical Research Council (MRC) randomised trial of palliative radiotherapy with two fractions or a single fraction in patients with inoperable non-small-cell lung cancer (NSCLC) and poor performance status. *Br J Cancer* 1992;65:934-41.
- 5 De Haes JCJM, van Knipperberg FCE, Neijt JP. Measuring psychological and physical distress in cancer patients: structure and application of the Rotterdam symptom checklist. *Br J Cancer* 1990;62:1034-8.
- 6 Zigmond AS, Snaith RR. The hospital anxiety and depression scale. *Acta Psychiatr Scand* 1983;67:361-70.
- 7 De Haes JCJM, Olschewski M, Fayers P, Visser MRM, Cull A, Hopwood P, et al. The Rotterdam Symptom Checklist (RSCL). Groningen, Northern Centre for Healthcare Research, The Netherlands, 1996.
- 8 Saunders M, Dische S, Barrett A, Harvey A, Gibson D, Parmar M, on behalf of the CHART Steering Committee. Continuous hyperfractionated accelerated radiotherapy (CHART) versus conventional radiotherapy in non-small cell lung cancer: a randomised multicentre trial. *Lancet* 1997;350:161-5.
- 9 Non-small Cell Lung Cancer Collaborative Group. Chemotherapy in non-small cell lung cancer: a meta-analysis using updated data on individual patients from 52 randomised clinical trials. *BMJ* 1995;311:899-909.
- 10 Cullen MH, Billingham LJ, Woodroffe CM, Chetiyawardana AD, Gower NH, Joshi R, et al. Mitomycin, ifosfamide, and cisplatin in unresectable non-small cell lung cancer: effects on survival and quality of life. *J Clin Oncol* 1999;17:3188-94.

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Effects of stretching before and after exercising on muscle soreness and risk of injury: systematic review

Rob D Herbert, Michael Gabriel

Abstract

Objective To determine the effects of stretching before and after exercising on muscle soreness after exercise, risk of injury, and athletic performance.

Method Systematic review.

Data sources Randomised or quasi-randomised studies identified by searching Medline, Embase, CINAHL, SPORTDiscus, and PEDro, and by recursive checking of bibliographies.

Main outcome measures Muscle soreness, incidence of injury, athletic performance.

Results Five studies, all of moderate quality, reported sufficient data on the effects of stretching on muscle soreness to be included in the analysis. Outcomes seemed homogeneous. Stretching produced small and statistically non-significant reductions in muscle soreness. The pooled estimate of reduction in muscle soreness 24 hours after exercising was only 0.9 mm on a 100 mm scale (95% confidence interval -2.6 mm to 4.4 mm). Data from two studies on army recruits in military training show that muscle stretching before exercising does not produce useful reductions in injury risk (pooled hazard ratio 0.95, 0.78 to 1.16).

Conclusions Stretching before or after exercising does not confer protection from muscle soreness. Stretching before exercising does not seem to confer a practically useful reduction in the risk of injury, but

the generality of this finding needs testing. Insufficient research has been done with which to determine the effects of stretching on sporting performance.

Introduction

Many people stretch before or after engaging in athletic activity. Usually the purpose is to reduce muscle soreness after exercising, to reduce risk of injury, or to improve athletic performance.¹⁻⁷

This systematic review synthesises research findings of the effects of stretching before and after exercising on delayed onset muscle soreness, risk of injury, and athletic performance.

Methods

Inclusion and exclusion criteria

The review included English language randomised or quasi-randomised studies that investigated the effects of any stretching technique, immediately before or after exercising, on delayed onset muscle soreness, risk of injury, or athletic or sporting performance. Studies were included only if stretching was conducted before or after exercising.

Search strategy

Relevant studies were identified by searching Medline (1966 to February 2000), Embase (1988 to February 2000), CINAHL (1982 to January 2000), SPORTDiscus

(1949 to December 1999) and PEDro (to February 2000). More details are given on bmj.com

Assessment of study quality

Methodological quality was assessed independently by two assessors with the PEDro scale.^{8,9} Only studies scoring at least 3 were considered in the initial analysis.

Data extraction

To facilitate pooling, soreness scores were converted to percentages of the maximum possible score. For ease of interpretation, soreness data are reported as mm on a 100 mm analogue scale; negative values favour stretching.

Data synthesis

Results of comparable studies were pooled in meta-analyses. Meta-analysis of continuous outcomes (scores for muscle soreness) was performed with a fixed effects model.^{10,11} The time to event data, obtained directly from the authors, were analysed with Cox regression.

Results

Search results

Six studies investigated effects of stretching on delayed onset muscle soreness, and two investigated effects of stretching on the risk of injury (see bmj.com). Only one small and inconclusive study investigated effects of stretching on athletic performance, so these are not discussed further in this review.¹²

Methodological quality of included studies

The methodological quality of the studies was generally moderate. The range of quality scores was 2-7 (mean 4.1) out of 10. Often a report did not clearly specify that a criterion was met, and consequently we scored the study as not satisfying the criterion. Two studies did not provide sufficient data to permit inclusion in the meta-analysis.^{13,14}

Effect of stretching on delayed onset muscle soreness

The five studies included were reasonably homogeneous with respect to participants' characteristics and interventions. In all studies, participants were healthy young adults. Total stretch time per session varied from 300 seconds to 600 seconds, with the exception of one study in which total stretch time was only 80 seconds.¹⁵ Three studies evaluated stretching after exercising, and two evaluated stretching before exercising.¹⁵⁻¹⁸ As there was no evidence of heterogeneity in the outcomes of the studies ($P=0.97$ at 24 hours, $P=0.99$ at 48 hours, and $P=0.53$ at 72 hours), we combined studies using stretching both before and after exercising in the meta-analysis (fig 1).

The pooled mean effects of stretching on muscle soreness at 24, 48, and 72 hours after exercising were -0.9 mm (95% confidence interval -4.4 mm to 2.6 mm, $P=0.70$, $n=77$), 0.3 mm (-4.0 mm to 4.5 mm, $P=0.45$, $n=77$), and -1.6 mm (-5.9 mm to 2.6 mm, $P=0.77$, $n=67$), respectively. Sensitivity analysis indicated that the choice of threshold quality score and assumptions about correlations between repeated measures had little effect on this result.

Effect of stretching on risk of injury

Two studies evaluated the effects of stretching before exercising on the risk of specific leg injuries or all leg injuries in new military recruits undergoing 12 weeks

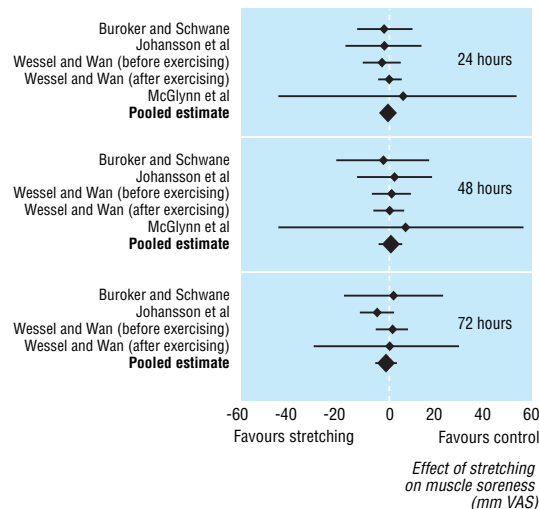


Fig 1 Effects of stretching on delayed onset muscle soreness at 24 hours, 48 hours, and 72 hours after exercise. (VAS=visual analogue scale)¹⁵⁻¹⁸

of initial training.^{19,20} Recruits were considered to have sustained an injury if they were unable to return to full duties without signs or symptoms in three days. The two studies yielded similar estimates of risk reduction (hazard ratios 0.92 (0.52 to 1.61) and 0.95 (0.77 to 1.18); fig 2).

Risks of injury in the two studies differ because injury is defined differently. Time to event data (2630 subjects, 65 platoons) were combined; 1284 subjects (32 platoons) were allocated to stretch groups and 1346 (33 platoons) to control groups. The discrepancy in sample size occurred because subjects were quasi-randomly allocated to an odd number of platoons by military personnel who did not participate in the studies, and then platoons were randomly allocated to groups by the experimenters. A total of 181 injuries occurred in stretch

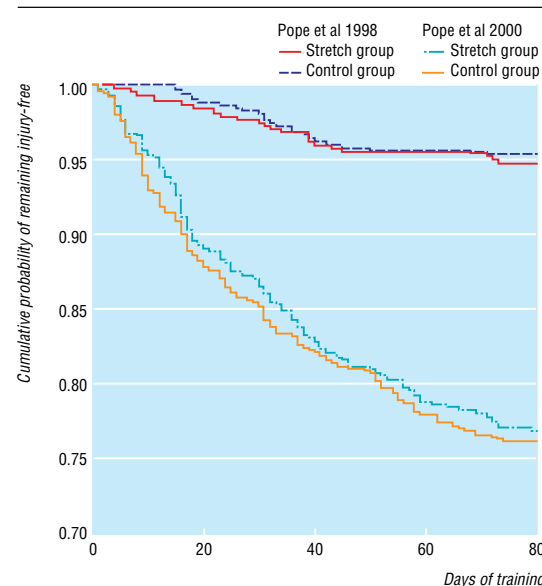


Fig 2 Survival curves from studies of Pope et al 1998 and Pope et al 2000, showing risk of injury in army recruits undergoing training^{19,20}

What is already known on this topic

Reviews of the effects of stretching before exercise have drawn conflicting conclusions

The literature on effects of stretching before and after exercising on muscle soreness and risk of injury has not been systematically reviewed

What this study adds

Stretching before and after exercising does not confer protection from muscle soreness

Stretching before exercise does not seem to confer a practically useful reduction in the risk of injury

groups and 200 injuries in control groups. Survival curves for stretch and control groups were similar (fig 2). The pooled estimate of the hazard ratio for the stretch factor was 0.95 (0.78 to 1.16, $P=0.61$).

Discussion

Eliminating potential bias

Our results are consistent with at least one review of the effects of stretching, but not others.²¹⁻²³ Unlike earlier reviews, we used a systematic review methodology to eliminate potential sources of bias as far as possible, but this does not guarantee the absence of bias. Our review may have been biased by publication bias or by inclusion only of studies reported in English.^{24 25} Both factors would be expected to inflate estimates of the effects of treatments, yet we found that stretching has no effect on delayed onset muscle soreness or on risk of injury. When we performed a less sensitive search for studies in languages other than English we found no studies that satisfied the inclusion criteria. The PEDro scale, which we used to discriminate between studies of different quality, has not been fully validated. Use of the PEDro scale is, however, unlikely to have biased our conclusions as study findings were consistent (fig 1).

Effect of stretching on delayed onset muscle soreness

The results of five studies (77 subjects) imply that stretching reduces soreness in the 72 hours after exercising by, on average, less than 2 mm on a 100 mm scale. Most athletes will consider effects of this magnitude too small to make stretching to prevent later muscle soreness worth while.

Effects of stretching on risk of injury

The pooled estimate from two studies was that stretching decreased the risk of injury by 5%. This effect was statistically non-significant. Even if this effect was not simply a sampling error it would not be large enough to be of practical significance. In army recruits, whose risk of injury in the control condition is high (approximately 20% over the training period of 12 weeks), a 5% reduction in relative risk implies a reduction in absolute risk of about 1%. Thus, on average, about 100 people stretch for 12 weeks to prevent one injury and (if the hazard reduction was constant) the average subject would need to stretch for 23 years to prevent one injury.¹⁹ Most athletes are exposed to lower risks of injury so the absolute risk reduction for most athletes is likely to be smaller still.^{26 27}

Although these data imply that the muscle stretching protocol used in these studies does not appreciably reduce risk of injury in army recruits undergoing military training, it is not possible to rule out with certainty a clinically worthwhile effect of other stretch protocols on risk of injury in other populations. It would be particularly interesting to determine if more prolonged stretching carried out by recreational athletes over many months or years can produce meaningful reductions in risk of injury.

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- DeVries HA. Prevention of muscular distress after exercise. *Res Q* 1961;32:177-85.
- DeVries HA. Electromyographic observations of the effects of static stretching upon muscular distress. *Res Q* 1961;32:468-79.
- Gleim GW, McHugh MP. Flexibility and its effects on sports injury and performance. *Sports Med* 1997;24:289-99.
- Cross KM, Worrell TW. Effects of a static stretching program on the incidence of lower extremity musculotendinous strains. *J Athletic Training* 1999;34:11-4.
- Hartig DE, Henderson JM. Increasing hamstring flexibility decreases lower extremity overuse injuries in military basic trainees. *Am J Sport Med* 1999;27:173-6.
- Gleim GW, Stachenfeld NS, Nicholas JA. The influence of flexibility on the economy of walking and jogging. *J Orthop Res* 1990;8:814-23.
- Handel M, Horstmann T, Dickhuth HH, Gulch RW. Effects of contract-relax stretching training on muscle performance in athletes. *Eur J Appl Physiol* 1997;76:400-8.
- 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. *J Clin Epidemiol* 1998;51:1235-41.
- Moseley AM, Maher C, Herbert RD, Sherrington C. Reliability of a scale for measuring the methodological quality of clinical trials. *Proceedings of the Cochrane colloquium*. Rome, Italy: Cochrane Centre, 1999:39.
- NHS Centre for Reviews and Dissemination. *Undertaking systematic reviews of research on effectiveness—CRD guidelines for those carrying out or commissioning reviews*. York: University of York, 1996.
- Laird NM, Mosteller F. Some statistical methods for combining experimental results. *Int J Technol Assess Health Care* 1990;6:5-30.
- Wilson GJ, Elliott BC, Wood GA. Stretch shorten cycle performance enhancement through flexibility training. *Med Sci Sports Exerc* 1992;24:116-23.
- High DM, Howley ET, Franks BD. The effects of static stretching and warm-up on prevention of delayed-onset muscle soreness. *Res Q* 1989;60:357-61.
- Gulick DT, Kimura IF, Sitler M, Paolone A, Kelly JD. Various treatment techniques on signs and symptoms of delayed onset muscle soreness. *J Athletic Training* 1996;31:145-52.
- Johansson PH, Lindstrom L, Sundelin G, Lindstrom B. The effects of pre-exercise stretching on muscular soreness, tenderness and force loss following heavy eccentric exercise. *Scand J Med Sci Sports* 1999;9: 219-25.
- Buroker KC, Schwane JA. Does postexercise static stretching alleviate delayed muscle soreness? *Physician Sportsmed* 1989;17:65-83.
- McGlynn GH, Laughlin NT, Rowe V. Effect of electromyographic feedback and static stretching on artificially induced muscle soreness. *Am J Phys Med* 1979;58:139-48.
- Wessel J, Wan A. Effect of stretching on the intensity of delayed-onset muscle soreness. *Clin J Sports Med* 1994;4:83-7.
- Pope RP, Herbert RD, Kirwan JD, Graham BJ. A randomized trial of pre-exercise stretching for prevention of lower-limb injury. *Med Sci Sport Ex* 2000;32:271-7.
- Pope RP, Herbert RD, Kirwan JD. Effects of ankle dorsiflexion range and pre-exercise calf muscle stretching on injury risk in army recruits. *Australian J Physiother* 1998;44:165-77.
- Shrier I. Stretching before exercise does not reduce the risk of local muscle injury: a critical review of the clinical and basic science literature. *Clin J Sports Med* 1999;9:221-7.
- Smith CA. The warm-up procedure: to stretch or not to stretch. A brief review. *J Orthop Sports Phys Ther* 1994;19:12-7.
- Safran MR, Seaber AV, Garrett WE. Warm-up and muscular injury prevention. An update. *Sports Med* 1989;8:239-49.
- Thornton A, Lee P. Publication bias in meta-analysis: its causes and consequences. *J Clin Epidemiol* 2000;53:207-16.
- Grégoire G, Derderian F, Le Lorier J. Selecting the language of the publications included in a meta-analysis: is there a Tower of Babel bias? *J Clin Epidemiol* 1995;48:159-63.
- Glasziou PP, Irwig LM. An evidence based approach to individualising treatment. *BMJ* 1995;311:1356-9.
- Herbert RD. Critical appraisal of clinical trials. II: Estimating the magnitude of treatment effects when outcomes are measured on a dichotomous scale. *Australian J Physiother* 2000;46:309-13.

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