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# Hamstring Stretches - Frequency Required to Maintain Knee Extension Range of Motion

# The frequency of hamstring stretches required to maintain knee extension range of motion following an initial six-week stretching programme


## ABSTRACT

Stretching exercises are commonly prescribed in training and rehabilitation programmes. The purpose of this study was to determine the frequency of on-going hamstring stretching required to maintain knee extension range of motion (ROM) following an initial stretching programme. A test-retest randomised control trial was undertaken. Sixty-three healthy male participants were randomly assigned to two stretch groups and a control group. Active knee extension (AKE) stretches were performed five days a week for an initial six weeks. Stretch group 1 then reduced the frequency of stretching to three days per week, and stretch group 2, to one day per week, for a further six weeks. The control group did not stretch. Active knee extension ROM was measured at baseline, weeks six and 12. A significant improvement in AKE ROM was observed in stretch group 1 (17.5° SD 11.8°) and 2 (18.8° SD 7.1°) after the initial six weeks of stretching ($p < 0.05$). After six-weeks of on-going stretching group 1 maintained their improvement in ROM, whereas stretch group 2 lost ROM. The difference between stretching groups was significant ($p < 0.05$) and no change in ROM was observed in the control group. These results indicate that an on-going hamstring stretching programme with a frequency of three times a week is required to maintain the initial improvement in ROM.



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Key words: hamstrings, extensibility, on-going stretching




## INTRODUCTION

Stretching exercises are commonly prescribed during warm-up and cool-down protocols, and training and rehabilitation programmes, with the aim of improving muscle extensibility and joint range of motion (ROM) (Chan et al 2001, Reid and McNair 2004, Small et al 2008, Smith 1994, Willy et al 2001). Research has demonstrated that a stretching programme to the hamstring muscle group consisting of 15-60 seconds, one to three repetitions per day, five days a week, for six weeks is sufficient to elicit significant changes in knee extension ROM (Bandy and Irion 1994, Bandy et al 1997, Davis et al 2005, Decoster et al 2005, Reid and McNair 2004, Russell et al 2010, Willy et al 2001). While research supports the effect of stretching, it has been suggested that improvements gained from stretching programmes are short-lived and start to diminish following the cessation of stretching (Rubley et al 2001, Willy et al 2001). However, it is unclear how often a stretch needs to be performed each week to maintain the initial improvements in ROM.

Two studies have investigated the effect of on-going stretching following an initial stretching programme (Rancour et al 2009, Wallin et al 1985). Wallin et al (1985) investigated the effect of 30 days of proprioceptive neuromuscular facilitation (PNF) and ballistic stretching, and 30 days of on-going PNF stretching with different stretching frequencies from one to five times a week. The authors suggested that on-going stretching, once per week was sufficient to maintain the initial improvement. In a similar study, Rancour et al (2009) examined the effect of an on-going stretching programme of two to three times a week, following a four-week static hamstring muscle stretching programme. The results indicated that this continuing dosage was sufficient to maintain the initial increases in ROM. However, neither of these studies used a control group who did not undertake a stretching programme. In addition, research has demonstrated that the compliance rates with home exercise programmes are low and too many repetitions of the prescribed exercises can reduce compliance (Haynes 1979 Schneiders et al 1998, Sluijs et al 1993).

The hamstring muscle group is commonly acutely injured (Verrall et al 2001) and stretching is often used in the management of such injuries (Malliaropoulos et al 2004). Ensuring compliance and adherence to prescribed exercises has been shown to be a critical factor in outcomes of the exercise programmes and the frequency and number of the exercises prescribed also influences this compliance (Bassett 2003). Therefore, the purpose of the current study was to undertake a randomised control trial to determine the frequency of hamstring stretches required to maintain knee extension ROM following a six-week initial hamstring stretching programme. This study would also help determine the minimum number of stretches required to maintain ROM as this may improve compliance with on-going stretching programmes.

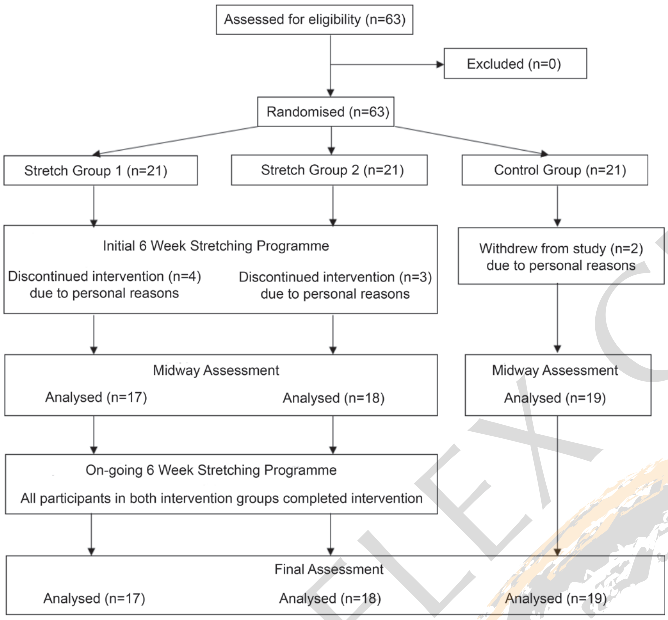
## METHODS

### Experimental Procedures

This was a 12-week study, using a test-retest randomised control trial design with repeated measures. Participants were randomly assigned using a computer-generated random number table to one of three groups: two intervention (stretch) groups and a control group. During an initial six-week programme, the frequency of stretches was the same for both stretch groups. For the six-week on-going stretching programme, stretch group 1 reduced the frequency of stretching to three times a week and stretch group 2 reduced to once a week. The control group did not perform any stretching exercises over the 12 week study period. Figure 1 outlines the flow of participants through the study.

This study was approved by the Auckland University of Technology (AUT) ethics committee.

**Figure 1: Flow diagram of randomisation, intervention and assessment process**




## Participants

Participants were recruited from the student population of the Auckland University of Technology (AUT). Prior to data collection, written and verbal explanations of the experimental procedures were provided, and written consent was gained. Participants were included in the study if they were male, between the ages of 18-40 years of age and had tight hamstring muscles defined as having greater than 20° loss of passive knee extension ROM using the passive knee extension test (Nelson and Bandy 2004). Only male participants were recruited as there are sex differences that affect ROM measures (Cornbleet and Woolsey 1996, Shephard et al 1990). Participants were excluded if they had any current lower limb injuries or low-back pain or had been participating in a stretching regime over the past three months.

Based on previous research by Reid and McNair (2004), to detect an initial 10° change in knee extension ROM with 80% power and $p < 0.05$, a sample size of approximately 48 participants was determined appropriate, with 16 in each group (www.biomath.info/power).

## Procedures

The AKE test, which has been shown to be highly reliable for measuring hamstring muscle tightness (r=0.99, Gajdosik and Lusin 1983), was used as the dependent variable. The participants were positioned in supine with the right hip and the knee flexed at 90°. This position was secured with a seat belt over the anterior pelvis and left thigh to reduce the potential movement of the pelvis during the test procedures, while the right thigh was in contact with a crossbar placed above the iliac crest. This was determined as the start position (Figure 2 ). Prior to assuming this position an electronic goniometer (Penny and Giles Blackwood Ltd., Gwent, UK); accurate to 0.5° (SD 0.41) (Piriyaprasarth et al 2008) was placed along a line between the greater trochanter of femur and the lateral femoral epicondyle, and a line between the lateral femoral epicondyle and lateral malleolus (Figure 3). Each participant was asked to actively extend the knee to the point at which he perceived significant stretching discomfort in the hamstring muscle group. This was determined as the end position (Figure 4). At this position, the knee extension ROM measurement was taken. Any lateral deviation or rotation at the hip or pelvic joints was closely monitored by the assessor. The measurement was repeated three times with a 10 second rest in between, taken only on the right lower limb as participants were instructed to stretch only their right hamstring muscles.

**Figure 2: Start position of the active knee extension (AKE) test.**

Prior to data collection, a pilot study assessing the intra-rater reliability of the AKE test was undertaken. Ten participants (mean age, 24.8 (SD 4.3) years; height, 172.9 (SD 6.1) cm; weight, 68.0 (SD 16.7) kg) from a sample of convenience took part in the reliability study. Using the data-collection procedures outlined earlier, two sets of measurements of active knee extension were completed on two separate occasions with 10 minutes intervals (Depino et al 2000, Spernoga et al 2001). The intra-class correlation coefficient (ICC, 2,1) for the paired data was 0.99, establishing excellent test-retest reliability (Bandy and Irion 1994, Bandy et al 1998, Ford et al 2005).

Knee extension ROM was measured at baseline, and then at weeks 6 and 12. The measurement was performed following a standardised warm-up on a stationary bike for five minutes on the same load (50 Watts).

The stretching intervention was undertaken in two stages. Participants in the stretch groups performed an active static stretch of the right hamstring muscle group, for 30 seconds,

**Figure 3: Placement of electronic goniometer. The proximal arm was positioned over the lateral aspect of femur and the distal arm on the lateral aspect of the fibula.**

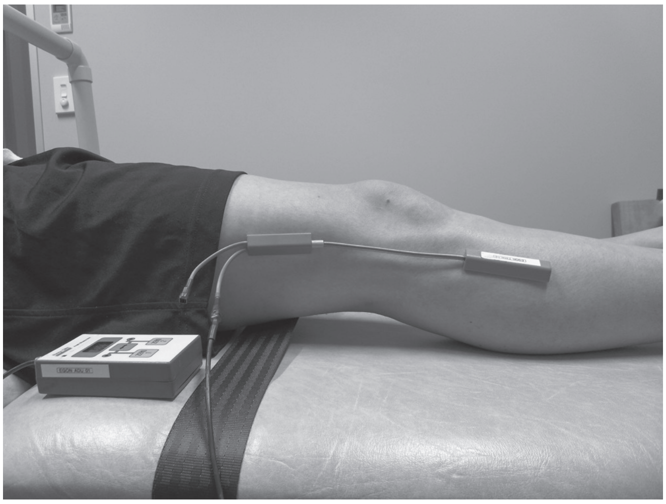


**Figure 4: Finish position of the active knee extension (AKE) test.**

three repetitions, once per day, five days a week, for six weeks. This programme was performed in the same manner as the AKE test described above.

Following this initial stretching period, participants in stretch group 1 reduced the frequency of stretching to three times per week and those in stretch group 2 stretched once a week for a further six weeks. All participants in the two intervention groups were educated in the stretching technique by a single researcher (JK) at baseline. To measure compliance with the stretching protocol, participants kept a diary of the stretching frequency and other physical activity, and the researcher contacted participants through email or text messages every three weeks to improve compliance. Participants were asked to record their compliance with the stretching intervention after each session and, for other physical activities on a weekly basis.

The control group did not stretch throughout the intervention period but their knee extension ROM was measured at the start and end of the trial. All participants were instructed not to alter their activity of daily living regimes throughout the duration of the study.

### Statistical Analyses

Descriptive statistics were analysed to determine the appropriateness of utilising parametric analysis. A two-factor (time and group) repeated ANOVA was utilised to determine any significant changes in knee extension ROM over time and to compare ROM differences between the three groups over time. The participant diaries were assessed for compliance via descriptive statistics. Statistical analysis was performed using SPSS statistical analysis software version 18 (SPSS Inc. Chicago, IL). The alpha level was set at 0.05.

## RESULTS

### Participants

A total of 63 participants were recruited (see Table 1). Nine participants withdrew from the study; four in stretch group 1, three in stretch group 2 and two in the control group. The main reason stated for the withdrawals were a lack of time to commit to the programme. The data from these participants were dealt with via an intention-to-treat analysis.

### Knee extension range of motion

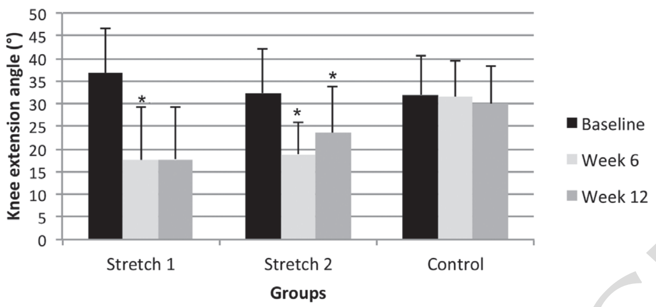
The two-factor repeated ANOVA found a significant effect for time ($p < 0.05$) and group, and a significant interaction between time and group ($p < 0.05$). Figure 5 displays the mean knee extension ROM for the stretch groups and the control group. The start angle for the test movement was 90° knee flexion and 0° was determined as full knee extension. Participants in stretch group 1 recorded a mean 36.6° (SD 9.8°) short of full knee extension at baseline, and participants in stretch group 2, a mean of 32.3° (SD 9.9°) short of full extension. These differences in ROM were not significant ($p>0.05$).

**Table 1: Participant's age, height, mass and baseline knee extension range of motion. Independent t-tests indicated no significant differences at baseline (p>0.05). Data are means and standard deviations**

| Groups (n) | Age (years) | Height (cm) | Mass (kg) | Baseline ROM (degrees) |
|---|---|---|---|---|
| Control (21) | 23.0 (5.4) | 179.0 (6.7) | 77.7 (13.3) | 31.9 (8.5) |
| Stretch 1 (21) | 23.2 (5.7) | 177.1 (8.0) | 76.4 (13.2) | 36.6 (9.8) |
| Stretch 2 (21) | 22.5 (4.3) | 179.6 (7.7) | 74.8 (10.1) | 32.3 (9.9) |
| Group mean (63) | 22.9 (5.1) | 178.6 ( 7.5) | 76.3 (12.1) | |

Following the initial six-week stretching intervention participants in stretch group 1 improved significantly to a mean of 17.5° (SD 11.8°) ($p < 0.05$). This corresponded to 19.1° increase in ROM. At week 12 these participants had maintained their increased ROM at 17.7° (SD 11.7 °). This difference was not significant ($p > 0.05$). In stretch group 2, ROM improved significantly to a mean 18.9° (SD 7.2 °) after the initial six week stretching intervention ($p < 0.05$). This corresponded to a 13.3° improvement in ROM. At week 12, ROM for group 2 participants had reduced to 23.5 (SD 10.3 °), a 4.6 ° reduction in ROM. This difference was significant ($p < 0.05$). Participants in the control group had a mean 31.9° (SD 8.5°) short of full knee extension at the baseline, 31.5° (SD 7.8°) at week six and 29.9° (SD 8.5°) at week 12. These differences were not significant ($p > 0.05$). Overall compliance of the intervention groups to the hamstring stretching programme was 93%. There were no significant differences in compliance rates between groups ($p>0.05$). A qualitative examination of the participants' diaries indicated that none had undertaken additional activities that may have affected the results.

**Figure 5: The knee extension range of movement for the intervention groups and the control group at baseline, week 6 and week 12. Data are means and standard deviations; *p<0.05.**




## Effect size

The effect sizes of the initial hamstring stretching intervention were calculated by taking the mean difference of the experimental and control group changes in knee extension ROM and dividing this figure by the pooled standard deviation of the experimental and control groups (Cohen, 1988). Stretch groups 1 and 2 both demonstrated a large effect size, 1.75 and 1.56 respectively, during the initial stretching intervention.

## DISCUSSION

The main findings of this study were that a six-week static hamstring stretching programme significantly improves knee extension ROM, and that an on-going stretching programme of three times per week is required in order to maintain the improvement in ROM following an initial stretching programme.

The initial changes in ROM over the first six weeks are consistent with previous stretching studies (Bandy et al 1997, Reid and McNair 2004, Roberts and Wilson 1999, Russell et al 2010). Following a further six weeks of stretching, stretch group 1 successfully maintained this initial improvement with an on-going stretching frequency of three times a week, while stretch group 2 lost ROM with an on-going stretching frequency of once a week. In comparison, the control group did not demonstrate significant change in ROM over the course of the study.

A number of studies have suggested that improvements in ROM following a stretching programme are short lived (a maximum of four weeks) and start to diminish following the stretching intervention (Depino et al 2000, Ford and McChesney 2007, Rubley et al 2001, Willy et al 2001). Willy et al (2001) examined the effect of cessation and resumption of static hamstring muscle stretching on knee ROM. The study demonstrated that any initial improvements in ROM were lost four weeks after stopping the stretching intervention. Once the stretching programme was re-introduced the initial gains in ROM were restored. These findings indicate a need to continue a stretching programme once the initial gains in ROM have been achieved, and the results of the current study are consistent with this.

Only two other studies have investigated the frequency of on-going stretching (Rancour et al 2009, Wallin et al 1985). Wallin et al. (1985) investigated the effect of 30 days of PNF and ballistic stretching, followed by 30 days of on-going PNF stretching alone. Passive plantar-flexion and hip adduction and extension angles were measured at baseline, and after 14, 30 and 60 days. In the initial stretching programme, three groups performed PNF stretching and one group performed ballistic stretching, three times a week for 30 days. After the initial stretching period, the three groups performed the same PNF stretching protocol once, three or five times a week, respectively, for another 30 days. The results showed that following 30 days of on-going PNF stretching all groups demonstrated a significant increase in ROM. The authors concluded that on-going stretching of once a week was sufficient to maintain the initial improvement in ROM. Their results are in contrast to the current study that demonstrated on-going stretching of once a week was not sufficient to maintain ROM following the initial improvement. These differences may be due to the different types of stretching techniques used (PNF and ballistic versus static stretching), and the differences in durations of on-going stretching programmes (30 days versus 42 days).

Rancour et al ( 2009) examined the effect of on-going stretching following a four-week static hamstring stretching programme. Participants were randomly assigned to one of two groups and both groups performed passive static hamstring stretching two repetitions of 30 seconds, twice a day, seven days per week, for four weeks. After the initial stretching programme, one group reduced the frequency of hamstring stretching to two to three times a week for four weeks, while another group ceased stretching. The results demonstrated that both groups had a significant improvement in hip flexion ROM after the initial four weeks of stretching. In the current study, the magnitude of the initial changes in ROM of the stretch groups over the first six weeks was 19.1° and 13.5°, respectively. Rancour et al (2009) demonstrated improvements of 19.2° and 20.5°, respectively over the same period; however, the group performing the on-going stretching regime maintained the improvement while the group that ceased stretching over the next four weeks, lost an average 6.7° in ROM. The authors concluded that on-going stretching with a frequency of two or three times a week was sufficient to maintain the initial improvement in ROM.

The results of the study by Rancour et al (2009) are similar in magnitude to the current study but also greater than other studies using a similar frequency of stretching. Reid and McNair (2004) demonstrated an average 10.1° increase in knee extension ROM after six weeks of hamstring stretching in school-aged individuals. This may indicate that the optimal frequency of initial stretching has yet to be determined or that increases in ROM may vary in different population groups. However, Rancour et al (2009) did not provide a set frequency of on-going stretching but instead allowed participants to decide whether to stretch two or three times a week. For this reason, it is difficult to conclude whether the optimal frequency of on-going stretching is two or three times a week. With respect to the optimal frequency of on-going stretching, the results of this study are consistent with the current study that to maintain an initial improvement in ROM three times a week of on-going stretching is required. Finally, in comparison to the current study, Rancour et al (2009) and Wallin et al (1985) did not have a true control group.

From a clinical and practical perspective, an on-going stretching programme with reduced frequency allows maintenance of the benefits of stretching exercises with minimal effort and potentially improves participants' compliance with on-going stretching exercises. Although stretching is commonly prescribed in clinical practice, research has shown that once a client is discharged from therapy, compliance rate with the home exercise programmes are low and too many exercises can reduce compliance (Haynes 1979, Henry et al 1999, Schneiders et al 1998, Sluijs et al 1993). In the current study, both stretching groups maintained a high level of compliance, averaging 93%, throughout the study. Possible reasons for this high compliance may include the reduced frequency of stretching required, clear written and verbal instruction, and continuous reminders and regular follow-up by the research team (Eakin et al 2007, Jacobs et al 2004, Schneiders et al 1998).

A number of limitations were associated with this study. Recruitment of participants for this study was primarily carried out within a university setting and only healthy and university-aged individuals were included in the study. The findings, therefore, may not be directly applicable to injured or older populations. Despite regular reminders and follow-up, nine of the 63 participants withdrew from the study. An intention-to-treat analysis was used to compensate for this. Finally, other variables such as force or muscle stiffness (Gajdosik 1991, Magnusson 1998, Reid and McNair 2004) associated with stretching interventions were not measured this study.

Future research examining structural changes associated with static stretching and whether these changes are maintained through on-going stretching is required. Future studies may also need to look at that whether different types of stretching (e.g. PNF versus static stretching) or stretching of different muscle groups have different effects on maintenance. Finally, as the results of this study are limited to a healthy university-age population, the effect of on-going stretching protocol of this study needs to be confirmed in different clinical populations such as elderly and females, and those with diseases that affect joint ROM such as osteoarthritis, and muscle injury.

## CONCLUSION

The results of the current study demonstrated that on-going hamstring stretching programmes of three times a week was required to maintain the increased ROM following an initial six week stretching intervention. Reducing the number and frequency of stretching exercises required from five to three times a week may enhance compliance, particularly, in populations where maintaining an appropriate range of motion is helpful to enhance performance and reduce the risk of injury and re-injury.

## KEY POINTS

- Stretching exercises are commonly prescribed to improve muscle extensibility and joint ROM, but on-going stretching exercises may be required to maintain any initial improvements in ROM.
- An initial stretching regime of 3×30 seconds, once per day, five days a week for six weeks to the hamstring muscles, significantly increases knee extension ROM.
- A frequency of three times a week is required with an on-going stretching programme for a further six weeks to maintain the initial improvement in knee extension ROM.



## REFERENCES

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

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

Bassett SF (2003) The assessment of patient adherence to physiotherapy rehabilitation. *New Zealand Journal Physiotherapy* 31: 60-66.

Chan SP, Hong Y, Robinson PD (2001) Flexibility and passive resistance of the hamstrings of young adults using two different static stretching protocols. *Scandinavian Journal of Medicine and Science in Sports* 11: 81-86.

Cohen J. (1988) Statistical Power Analysis for the Behavioural Sciences. Hillsdale, NJ: Lawrence Earlbaum Associates.

Cornbleet SL, Woolsey NB (1996) Assessment of hamstring muscle length in school-aged children using the sit-and-reach test and the inclinometer measure of hip joint angle. *Physical Therapy* 76: 850-855.

Davis DS, Ashby PE, McCale KL, McQuain JA, Wine JM (2005) The effectiveness of 3 stretching techniques on hamstring flexibility using consistent stretching parameters. *Journal of Strength and Conditioning Research* 19: 27-32.

Decoster LC, Cleland J, Altieri C, Russell P (2005) The effects of hamstring stretching on range of motion: a systematic literature review. *Journal of Orthopaedic and Sports Physical Therapy* 35: 377-387.

Depino GM, Webright WG, Arnold BL (2000) Duration of maintained hamstring flexibility after cessation of an acute static stretching protocol. *Journal of Athletic Training* 35: 56-59.

Eakin EG, Lawler SP, Vandelanotte C, Owen N (2007) Telephone interventions for physical activity and dietary behavior change: a systematic review. *American Journal of Preventive Medicine* 32: 419-434.

Ford GS, Mazzone MA, Taylor K (2005) The effect of four different durations of static hamstring stretching on passive knee-extension range of motion. *Journal of Sports Rehabilitation* 14: 95-107.

Ford P, McChesney J (2007) Duration of maintained hamstring ROM following termination of three stretching protocols. *Journal of Sport Rehabilitation* 16: 18-27.

Gajdosik R, Lusin G (1983) Hamstring muscle tightness. Reliability of an active-knee-extension test. *Physical Therapy* 63: 1085-1090.

Gajdosik RL (1991) Effects of static stretching on the maximal length and resistance to passive stretch of short hamstring muscles. *Journal of Orthopaedic and Sports Physical Therapy* 14: 250-255.

Haynes RB (1979) Determinants of compliance: The disease and the mechanics of treatment. In: Haynes RB, Taylor DW, Sackett D L (Eds) Compliance in Health Care. Baltimore: John Hopkins University Press.

Henry KD, Rosemond C, Eckert LB (1999) Effect of number of home exercises on compliance and performance in adults over 65 years of age. *Physical Therapy* 79: 270-277.

Jacobs AD, Ammerman AS, Ennett ST, Campbell MK, Tawney KW, Aytur SA, Marshall SW, Will JC, Rosamond WD (2004) Effects of a tailored follow-up intervention on health behaviors, beliefs, and attitudes. *Journal of Women's Health* 13: 557-568.

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

Malliaropoulos N, Papalexandris S, Papalada A, Papacostas E (2004) The role of stretching in rehabilitation of hamstring injuries: 80 athletes follow-up. *Medicine and Science in Sports and Exercise* 36: 756-759.

Nelson RT, Bandy WD (2004) Eccentric training and static stretching improve hamstring flexibility of high school males. *Journal of Athletic Training* 39: 254-258.

Piriyaprasarth P, Morris ME, Winter A, Bialocerkowski AE (2008) The reliability of knee joint position testing using electrogoniometry. *BMC Musculoskeletal Disorders* 9:6.

Rancour J, Holmes CF, Cipriani DJ (2009) The effects of intermittent stretching following a 4-week static stretching protocol: a randomized trial. *Journal of Strength and Conditioning Research* 23: 2217-2222.

Reid DA, McNair PJ (2004) Passive force, angle, and stiffness changes after stretching of hamstring muscles. *Medicine and Science in Sports and Exercise* 36: 1944-1948.

Roberts JM, Wilson K (1999) Effect of stretching duration on active and passive range of motion in the lower extremity. *British Journal of Sports Medicine* 33: 259-263.

Rubley MD, Brucker JB, Knight KL, Ricard MD, Draper DO (2001) Flexibility retention 3 weeks after a 5-day training regime. *Journal of Sport Rehabilitation* 10: 105-112.

Russell PJ, Decoster LC, Enea D (2010) Effects of gastrocnemius, hamstring, and combined stretching programs on knee extensibility. *Athletic Training and Sports Health Care* 2: 67-73.

Schneiders AG, Zusman M, Singer KP (1998) Exercise compliance in acute low back pain patients. *Manual Therapy* 3: 147-152.

Shephard RJ, Berridge M, Montelpare W (1990) On the generality of the "sit and reach" test: an analysis of flexibility data for an aging population. *Research Quarterly for Exercise and Sport* 61: 326-330.

Sluijs EM, Kok GJ, van der Zee J (1993) Correlates of exercise compliance in physical therapy. *Physical Therapy* 73: 771-782; discussion 783-776.

Small K, Mc Naughton L, Matthews M (2008) A systematic review into the efficacy of static stretching as part of a warm-up for the prevention of exercise-related injury. *Research in Sports Medicine* 16: 213-231.

Smith CA (1994) The warm-up procedure: to stretch or not to stretch. A brief review. *Journal of Orthopaedic and Sports Physical Therapy* 19: 12-17.

Spernoga SG, Uhl TL, Arnold BL, Gansneder BM (2001) Duration of maintained hamstring flexibility after a one-time, modified hold-relax stretching protocol. *Journal of Athletic Training* 36: 44-48.

Verrall G, Slavotinek J, Barnes P, Fon G Spriggins A (2001) Clinical risk factors for hamstring muscle strain injury: a prospective study with correlation of injury by magnetic resonance imaging *British Journal of Sports Medicine* 35:435-439.

Wallin D, Ekblom B, Grahn R, Nordenborg T (1985) Improvement of muscle flexibility. A comparison between two techniques. *American Journal of Sports Medicine* 13: 263-268.

Willy RW, Kyle BA, Moore SA, Chleboun GS (2001) Effect of cessation and resumption of static hamstring muscle stretching on joint range of motion. *Journal of Orthopaedic and Sports Physical Therapy* 31: 138-144.

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