# Randomised trial of the effects of four weeks of daily stretch on extensibility of hamstring muscles in people with spinal cord injuries

**Lisa A Harvey[1], Adrian J Byak[1], Marsha Ostrovskaya[1], Joanne Glinsky[1], Lyndall Katte[2] and Robert Herbert[3]**

[1]*Royal Rehabilitation Centre, Sydney* [2]*The Prince Henry Hospital, Sydney* [3]*The University of Sydney*

The aim of this assessor-blind randomised controlled trial was to determine the effect of four weeks of 30 minute stretches each weekday on extensibility of the hamstring muscles in people with recent spinal cord injuries. A consecutive sample of 16 spinal cord-injured patients with no or minimal voluntary motor power in the lower limbs and insufficient hamstring muscle extensibility to enable optimal long sitting were recruited. Subjects' legs were randomly allocated to experimental and control conditions. The hamstring muscles of the experimental leg of each subject were stretched with a 30 Nm torque at the hip for 30 minutes each weekday for four weeks. The hamstring muscles of the contralateral leg were not stretched during this period. Extensibility of the hamstring muscles (hip flexion range of motion with knee extended, measured with a 48 Nm torque at the hip) of both legs was measured by a blinded assessor at the commencement of the study and one day after the completion of the four-week stretch period. Changes in hamstring muscle extensibility from initial to final measurements were calculated. The effect of stretching was expressed as the mean difference in these changes between stretched and non-stretched legs. The mean effect of stretching was 1 degree (95% CI -2 to 5 degrees). Four weeks of 30 minute stretches each weekday does not affect the extensibility of the hamstring muscle in people with spinal cord injuries. **[Harvey LA, Byak AJ, Ostrovskaya M, Glinsky J, Katte L and Herbert R (2003): Randomised trial of the effects of four weeks of daily stretch on extensibility of hamstring muscles in people with spinal cord injuries. *Australian Journal of Physiotherapy* 49: 176-181]**

Key words: Contracture; Muscles; Quadriplegia; Rehabilitation

## Introduction

Extensibility of the hamstring muscles is important for people with spinal cord injuries, particularly those who have paralysis of hip, trunk and abdominal muscles and have the potential to transfer and dress independently. This includes people with spinal cord lesions below C5. Adequate hamstring muscle extensibility enables these people to sit with knees extended and with the trunk's centre of mass anterior to the hip joint. From this position they can utilise passive tension in the paralysed hamstring muscles to prevent a forward fall (Harvey et al 2003). In contrast, insufficient extensibility in the hamstring muscles prevents adequate hip flexion so that the centre of mass falls posterior to the hips when sitting with the knees extended, causing the person to fall backwards. This necessitates use of the upper limbs to support the trunk and prevents performance of functional tasks.

Poor hamstring muscle extensibility is a common problem in people with spinal cord injury (Bromley 1976, Somers 1992). For this reason physiotherapy is often directed at increasing extensibility in these muscles. Typically this is done with the application of regular stretch. Stretches used for this purpose are commonly applied manually by therapists each day for between 30 seconds and two minutes (Bandy et al 1997 and 1998, Lentell et al 1992).

Numerous animal studies have shown that prolonged stretch, such as is applied with serial casting, produces sustained increases in muscle and joint extensibility (see reviews by Akeson et al 1987, Gossman et al 1982, Herbert 1993). In contrast, few animal studies have examined the lasting effects of shorter periods of stretch and few clinical trials on patient populations have investigated the lasting effects of either long or short duration stretch interventions. A systematic review of studies on humans (Harvey et al 2002) identified 13 studies that examined the lasting effects of regular stretch (Bandy and Irion 1994, Bandy et al 1997 and 1998, Bohannon 1984, Godges et al 1993, Halbertsma and Goeken 1994, Hardy 1985, Lentell et al 1992, McCarthy et al 1997, Magnusson et al 1996, Medeiros et al 1977, Starring et al 1988, Tanigawa 1972). All 13 studies involved able-bodied subjects with normal muscle extensibility. Meta-analysis of the four moderate quality studies showed that, on average, stretching produced increases in range of motion of 6 degrees (95% CI 4 to 8 degrees) that were apparent at least one day after the cessation of the stretch program. Though none of the included studies were of high quality, this review suggests that stretching produces small lasting changes in range of motion in able-bodied subjects.

A more recent randomised trial investigated the effects of four weeks of 30 minute stretches administered each day to the ankles of people with spinal cord injuries (Harvey et al 2000). Surprisingly, this study found no effect of stretching (mean treatment effect of 0 degrees, 95% CI -3 to 3 degrees). It is possible that these negative results were due to the inclusion of some subjects with normal ankle mobility. Subjects with normal ankle mobility were included to simulate clinical practice where stretches are routinely administered to prevent ankle contractures. There was, however, no evidence that the effect of stretching was any greater in subjects with contracture.

The current study also sought to determine if a four-week program of stretch had lasting effects on muscle extensibility in spinal cord-injured individuals. In the current study, we examined the effect of stretching the hamstring muscles, and we included only subjects with limited hamstring muscle extensibility.

## Methods

***Subjects*** Consecutive inpatients from two spinal cord injury units in Sydney were invited to participate in the study. To be eligible for inclusion, subjects had to have sustained a spinal cord injury within the past 12 months, have commenced sitting out of bed following the initial injury and have less than 110 degrees passive hip flexion with the knee extended (this is generally considered insufficient hamstring muscle extensibility to enable unsupported sitting on a bed with the knees extended). The inability to sit unsupported in long sitting poses a significant clinical problem that is generally managed with stretch interventions. Subjects were excluded if they had more than small amounts of voluntary activity in the muscles around the hips and knees (that is, more than grade 2/5 motor strength); were unlikely to remain in the unit for four weeks; had a history of trauma to the pelvis or upper leg; or were unable to tolerate stretch (due to pain, sacral pressure area or medical complication).

Sixteen patients participated in the study. A power calculation performed prior to commencement indicated that this sample size would provide a 95% probability of detecting a 5 degree change in hip flexion, assuming a standard deviation of 5 degrees and alpha of 0.05. In this calculation, we conservatively assumed outcomes on right and left legs would be uncorrelated.

The study received ethical approval from the appropriate institutions and informed consent to participate was obtained from all subjects.

***Measurement of hamstring muscle extensibility*** The extensibility of the hamstring muscles of both legs was determined by measuring passive hip flexion with the application of a standardised torque while the knee was maintained in extension. Subjects lay supine with the contralateral leg and pelvis strapped to the bed. Measurements were made with a device attached to a physiotherapy plinth. The device (Harvey et al 2003) was designed specifically for this purpose (see Figure 1).

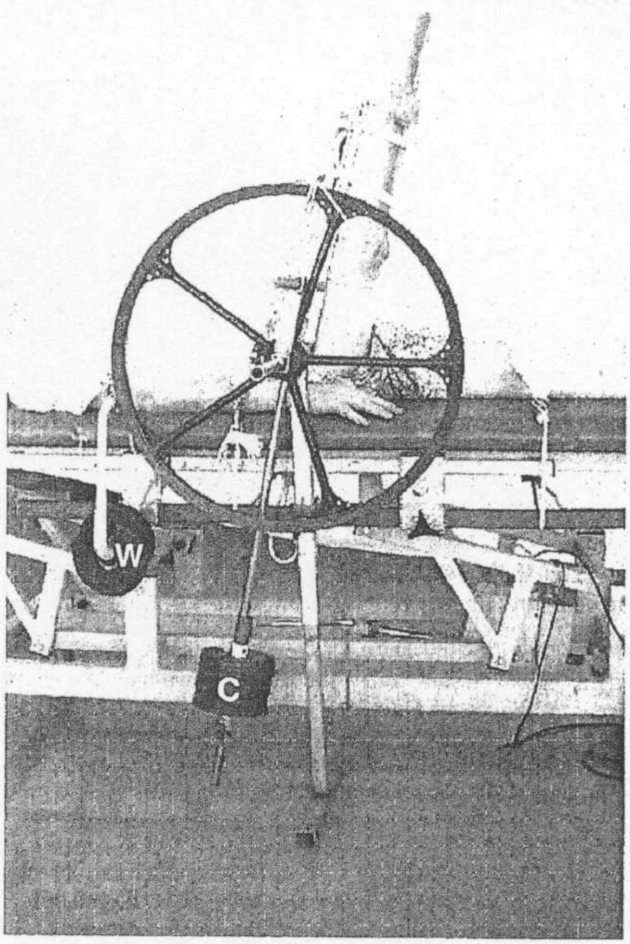


**Figure 1.** The testing device. The subject's leg was placed in a knee extension splint. A wheel was attached to the side of the bed and the splint. Weights (W) were hung from the rim of the wheel to rotate the leg splint. The torque due to the weight of the leg and splint was eliminated by counterweights (C). An inclinometer was used to determine hip angle.

***Device*** The device consisted of a wheel mounted on the side of the physiotherapy plinth. A leg splint was attached to the wheel, and the two rotated together. The leg splint prevented knee flexion, hip abduction and rotation. A 48 Nm hip flexor torque was applied by hanging an 18 kg weight from the rim of the wheel. The wheel acted to ensure that the moment arm of the hip flexor torque remained constant (27 cm) regardless of hip angle. Hip flexion angle was measured with a digital inclinometer placed on the long axis of the knee extension splint. Zero degrees hip flexion indicated that the leg was lying flat on the bed and 90 degrees hip flexion indicated that the leg was raised perpendicular to the bed. The torque due to the weight of the leg and the knee extension splint was counterbalanced by adjustable counterweights attached to a long rod that extended proximally from the leg splint up

**Figure 2.** Flow of subjects through the study.

| | |
|---|---|
| Subjects with neurological loss admitted to the two Sydney spinal units over the 1 year study period | 61 |
| Number of subjects excluded | 45 |
| Reasons for exclusion: | |
| Hip flexion > 110 degrees | 6 |
| Lower limb motor power > 2/5 | 22 |
| Unlikely to remain at unit | 1 |
| History of trauma | 1 |
| Unable to tolerate stretch | 8 |
| Declined to be involved | 7 |
| Number of subjects randomised and followed up | 16 |

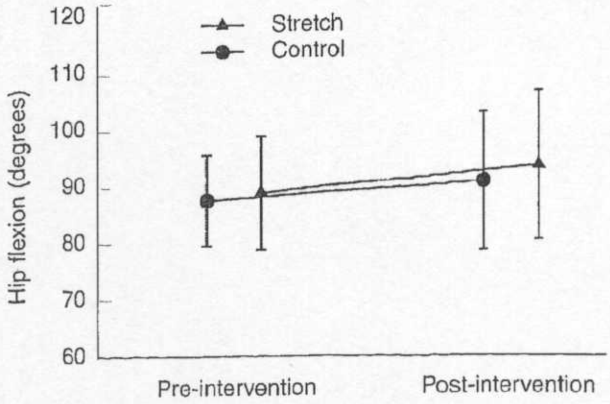


**Figure 3.** Mean (± SD) of differences between hip flexion range of motion attained with the application of 48 Nm torque of the treated and control leg at the commencement of the study and then after four weeks of stretch. A positive difference indicates that the treatment had an advantageous effect on the extensibility of the hamstring muscles in relation to the extensibility of the hamstring muscles on the non-treated leg.

towards the subject's head. The rod and counterweights rotated with the leg about the hip joint.

***Procedure*** Testing always followed the same format. The right leg was tested before the left leg. Two measurements were taken on each leg after a 3 min pre-stretch. In this way, reflex muscle activity around the hip and knee, if present, was minimised and most viscous deformation exhausted (Bohannon 1984, Magnusson et al 1995). The stretch was removed between the first and second measurements.

The testing device has been shown to have good reliability (Harvey et al 2003). Additional measures of the reliability of the device were obtained by comparing repeat measures of the control leg taken at the beginning and end of the study (four weeks apart). Reliability was expressed as an intra-class correlation coefficient (ICC 2,1; Shrout and Fleiss 1979).

***Experimental protocol*** After completion of initial measurements, one leg was randomly allocated to the experimental (stretch) condition and the other was allocated to the control (non-stretch) condition. A computer-generated random allocation schedule was produced prior to the study by one of the authors who was not otherwise involved in subject recruitment or allocation. To ensure concealment, the same person placed allocations in sealed, opaque, sequentially-numbered envelopes. The envelopes were not opened until after the initial tests had been performed. Subjects were considered to have entered the trial once the envelope was opened.

The hamstring muscles of the experimental leg were stretched for 30 minutes daily on five days each week for four weeks, using the same device as used for testing. The control leg received no hamstring stretches during this time.

The hamstring muscles were stretched with a 30 Nm torque (the torque attained by hanging 11.4 kilograms from the rim of a 27 cm wheel). This torque was selected after determining the magnitude of the torque commonly used by other researchers (Bandy and Irion 1994, Bandy et al 1997 and 1998, Bohannon 1984, Godges et al 1993, Halbertsma and Goeken 1994, Hardy 1985, Lentell et al 1992, McCarthy et al 1997), the stretch torque found to be tolerated by able-bodied individuals as well as paraplegics and quadriplegics with intact sensation, and the torque commonly applied by physiotherapists working in spinal injury units (Harvey et al 2003).

Subjects did not receive any other stretches to the hamstring muscles of either leg for the duration of the study. Legs were moved as required for nursing care but no subject received regular passive movements of the lower limbs. Some aspects of these patients' therapy and routine nursing care such as dressing and transferring may have required that subjects sit with hips flexed and knees extended (ie with the hamstring muscles in a stretched position). Efforts were made to minimise these events and nursing staff and therapists were instructed to place pillows under the knees when patients were long sitting. Despite this, it is possible that some activities placed the hamstring muscles in a stretched position. However, the effects of these and other co-interventions (eg antispasticity medication) on hamstring muscle extensibility would have been bilateral. The use of a randomised within-subjects design ensured that our estimates of benefits of the four-week stretch intervention could not be confounded by these factors.

Most nursing staff and occupational therapists were unaware of whether the right or left leg was receiving the stretch intervention. Subjects were not blinded, but paralysis of their legs provided them with limited opportunity to inadvertently bias results. Subjects were supervised most of the day and, unlike able-bodied individuals, they could not readily provide themselves with additional stretches. No subjects participated in sporting activities during the course of the study.

Subjects were re-tested one day after the completion of the four-week treatment period. Measurements were taken at least 24 hours after the last stretch by an independent therapist who was blinded to allocation. Patients were asked not to inform the blinded therapist of allocations.

***Data reduction and analysis*** Two measurements were obtained from each leg on each measurement occasion. Data from the two measurements were averaged. Mean changes from initial to final measures were calculated for both stretched and unstretched legs. Difference in these changes were then determined. A positive change indicates that stretch increased the extensibility of the hamstring muscles and a negative change indicates a reduction in extensibility. Paired *t*-tests were used to test for significant differences between stretched and unstretched legs in changes in extensibility from pre- to post-treatment measurements. Probabilities of less than 0.05 were considered significant. Data were analysed by intention-to-treat (Pocock 1983).

## Results

The flow of patients through the trial is given in Figure 2. Sixty-one patients with a recent spinal cord injury were admitted to the two spinal units over the study period. Of these, 38 patients did not meet the inclusion criteria or were excluded and seven declined to be involved. Of the 16 subjects randomised to conditions, six had paraplegia and 10 had quadriplegia. All subjects had upper motor neuron lesions and mean time since injury was three months (SD 1 month). The mean (SD) age, height and weight of subjects was 33 years (15 years), 179 cm (5 cm) and 70 kg (10 kg), respectively. Twelve subjects had minimal spasticity and four subjects had moderate spasticity in the lower limbs.

No subjects withdrew from the study. However, there were some minor deviations from the study protocol. Ten subjects missed between one and three of the 20 planned stretches due to a variety of reasons including extended leave from the unit, public holidays and staff leave. In these cases, the missed stretches were made up at the end of the study and testing was delayed by the corresponding number of days. One subject developed bilateral deep venous thromboses three days after commencing the study and was transferred to an acute medical hospital. He resumed daily stretches four weeks later and his testing was correspondingly delayed. Six subjects received an additional one or two stretch interventions. This was sometimes necessary to ensure that stretching continued up until the day before testing. Testing was never performed on a Monday after a weekend of no treatment. The trial protocol dictated that subjects receive 20 treatments to the stretch leg over 28 days; in practice subjects received a mean of 20 treatments (SD = 1 treatment) over a mean of 31 days (SD = 5 days).

One subject experienced increases in blood pressure consistent with autonomic dysreflexia when his hamstring muscles were stretched with the experimental device. These increases in blood pressure were accentuated by the supine position. Autonomic dysreflexia with stretch has been previously reported (McGarry et al 1982). For this reason, this subject's stretches were administered whilst he was seated in his wheelchair. His leg was placed on a high chair with the knee extended. The stretch torque administered to this subject was not standardised. An additional subject received one of his 20 stretches in sidelying due to a sacral pressure area.

The differences between the extensibility of subjects' treated and untreated hamstring muscles at the commencement of the study were small (see Figure 3). However, there was variability of the extensibility of the hamstring muscles across subjects. Some subjects had reasonable extensibility and others poor extensibility (mean hip flexion of untreated leg = 88 degrees; range = 77 degrees to 104 degrees).

The estimated reliability of the measurement procedure was reasonable considering repeat measurements were taken four weeks apart. The intra-class correlation coefficient, which describes the degree of agreement of the repeated measures, was 0.76 (95% CI 0.43 to 0.91). Seventy-five per cent of measurements obtained on the control leg at the commencement of the study were within 8 degrees of measurements obtained on the same leg four weeks later. It is likely that at least some of the differences between pre- and post-measures reflected real changes in hamstring muscle extensibility, so these estimates probably underestimate true reliability.

Figure 3 shows the change in extensibility of the hamstring muscles of the treated and non-treated legs over the course of the study. There was no change in the extensibility of treated or untreated legs. At four weeks, the mean difference between treated and untreated legs was 1 degree (95% CI -2 to 5 degrees). Thus stretching did not alter the extensibility of the hamstring muscles over and above changes in extensibility that occurred in the absence of stretching.

## Discussion

Four weeks of daily stretch failed to induce lasting increases in the extensibility of the hamstring muscles in people with recent spinal cord injuries (mean treatment effect of 1 degree, 95% CI -2 to 5 degrees). This was despite the application of stretches for 30 minutes each weekday, a much longer duration stretch than is typically applied by therapists. These results are consistent with a recent clinical trial (Harvey et al 2000) that also demonstrated no therapeutic effect from ankle stretching in people with spinal cord injuries (mean treatment effect 0 degrees, 95% CI -3 to 3 degrees).

There are possible explanations for the failure of this study to detect a treatment effect that require further investigation. It is possible that the stretch dosage was insufficient and that larger stretch torques applied over a longer period of time may have been more effective. The stretch torque (30 Nm) used in this study was selected after taking into account the magnitude of stretch torques physiotherapists typically apply to both able-bodied people and people with spinal cord injuries (20 Nm to 60 Nm when applying stretch for a few minutes; Harvey et al 2003) and after trialling different stretch torques on people with sensation prior to the study. A larger stretch torque was not applied because of the widely held belief that stretch normally associated with pain is harmful and may cause heterotopic ossification (Harvey 2000). However, the association between large stretch torques and heterotopic ossification has never been fully established and our concerns about applying large stretch torques may have been unwarranted.

People with spinal cord injuries who do not have sensation in the lower limbs provide their hamstring muscles with large stretches when dressing and transferring. It is estimated that stretch torque administered by sitting with the hips flexed and knees extended could exceed 144 Nm (calculations based on body mass of 75 kg, centre of mass of head, arms and trunk located 0.4 m from hips, and hip flexion angle of 130 degrees; Harvey et al 2003). The self-application of such large stretch torques with routine daily activities may explain our observation that some people with spinal cord injury develop excessive extensibility of the hamstring muscles over time. These uncontrolled observations suggest that stretch of sufficient magnitude may be effective. Future studies of the effects of stretching should look at the effect of larger stretch torques.

Failure to detect a treatment effect may also have been due to inadequate stretch time. Thirty minutes of daily stretch was chosen to represent the longest stretch that could be readily administered in clinical practice. It is possible that even longer daily stretches are required to induce lasting increases in muscle extensibility and that months rather than weeks of stretch are required.

In summary, this study examined the lasting effects of 30 minute stretches applied daily over four weeks. The failure to detect a treatment effect is of concern, given the importance of hamstring muscle extensibility and the time and resources devoted to administering stretch. Further studies are required to determine the critical stimulus required to induce lasting increases in muscle extensibility and to determine whether stretch is effective in patients confined to bed.

***Acknowledgments*** We acknowledge the financial assistance of the Motor Accident Authority of NSW and the support of the Rehabilitation Studies Unit, The University of Sydney. We thank Ms Julia Batty and the staff and patients of the Moorong and Prince Henry Hospital Spinals Unit for their assistance. We also thank Mr Bob Arnfield for his assistance in manufacturing the stretching device.

***Correspondence*** Dr Lisa Harvey, Moorong Spinal Injury Unit, Royal Rehabilitation Centre Sydney, PO Box 6, Ryde, New South Wales, 2112. E-mail: harveyl@doh.health.nsw.gov.au.

## References

Akeson WH, Amiel D, Abel MF, Garfin SR and Woo SL (1987): Effects of immobilization on joints. *Clinical Orthopaedics* 219: 28-37.

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

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

Bandy WJ, Irion JM and Briggler M (1998): 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* 27: 295-300.

Bohannon RW (1984): Effect of repeated eight-minute muscle loading on the angle of straight-leg raising. *Physical Therapy* 64: 491-497.

Bromley I (1976): Tetraplegia and Paraplegia: A Guide for Physiotherapists. New York: Churchill Livingstone.

Godges JJ, MacRae PG and Engelke KA (1993): Effects of exercise on hip range of motion, trunk muscle performance, and gait economy. *Physical Therapy* 73: 468-477.

Gossman MR, Sahrmann SA and Rose SJ (1982): Review of length-associated changes in muscle. Experimental evidence and clinical implications. *Physical Therapy* 62: 1799-1808.

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

Hardy L (1985): Improving active range of hip flexion. *Research Quarterly for Exercise and Sport* 56: 111-114.

Harvey L (2000): Contracture in spinal cord injured patients. PhD thesis, Faculty of Health Sciences, The University of Sydney.

Harvey LA, Batty J, Crosbie J, Poulter S and Herbert RD (2000): A randomised trial assessing the effects of 4 weeks of daily stretching on ankle mobility in patients with spinal cord injuries. *Archives of Physical Medicine and Rehabilitation* 81: 1340-1347.

Harvey LA, McQuade L, Hawthorne S and Byak A (2003): Quantifying the magnitude of torque physiotherapists apply when stretching the hamstring muscles of people with a spinal cord injury. *Archives of Physical Medicine and Rehabilitation* 84: 1072-1075.

Harvey LA, Crosbie J and Herbert RD (2002): Does regular stretch produce lasting increases in joint range of motion? A systematic review. *Physiotherapy Research International* 7: 1-13.

Herbert RD (1993): The prevention and treatment of stiff joints. In Crosbie J and McConnell J (Eds): Key Issues in Musculoskeletal Physiotherapy. London: Butterworth Heinemann, pp. 114-141.

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

McCarthy PW, Olsen JP and Smeby IM (1997): Effects of contract-relax stretching procedures on active range of motion of the cervical spine in the transverse plane. *Clinical Biomechanics* 12: 136-138.

McGarry J, Woolsey RM and Thompson CW (1982): Autonomic hyperreflexia following passive stretching to the hip joint. *Physical Therapy* 62: 30-31.

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

Magnusson SP, Simonsen E,B Aagaard P, Sorensen H and Kjaer M (1996): A mechanism for altered flexibility in human skeletal muscle. *Journal of Applied Physiology* 497: 291-298.

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

Pocock SJ (1983): Clinical Trials. A Practical Approach. Chichester: Wiley.

Shrout PE and Fleiss JL (1979): Intraclass correlations: Uses in assessing rater reliability. *Psychological Bulletin* 86: 420-428.

Somers MF (1992): Spinal Cord Injury: Functional Rehabilitation. Norwalk, Connecticut: Appleton and Lange.

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

Tanigawa M (1972): Comparison of the hold-relax procedure and passive mobilization on increasing muscle length. *Physical Therapy* 52: 725-734.