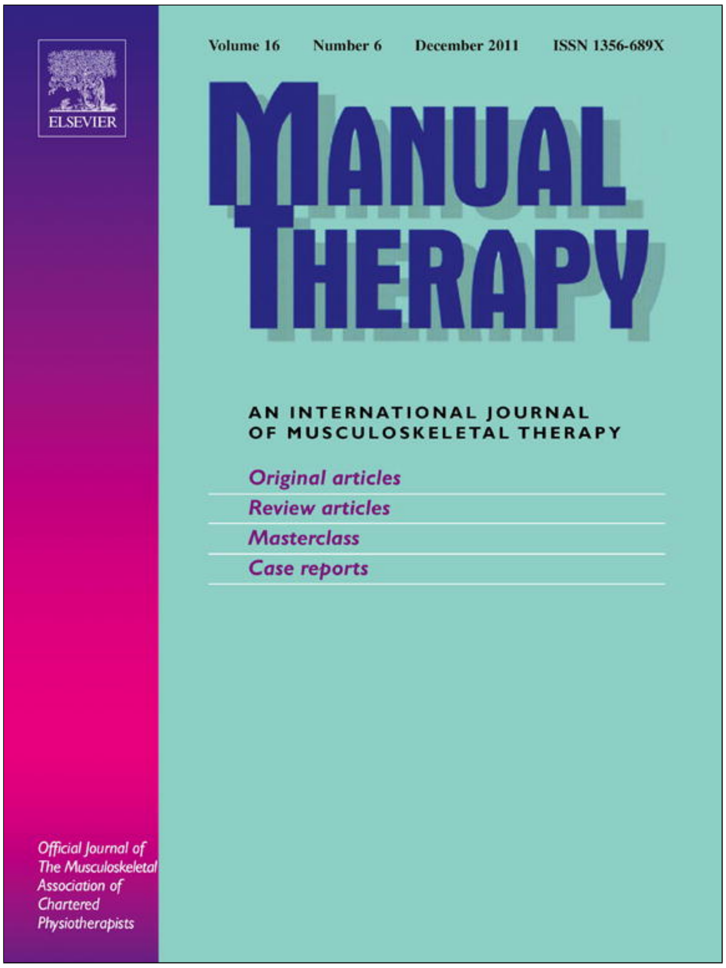
Volume 16
Number 6
December 2011
ISSN 1356-689X
ELSEVIER
MANUAL THERAPY
AN INTERNATIONAL JOURNAL OF MUSCULOSKELETAL THERAPY
Original articles
Review articles
Masterclass
Case reports
Official Journal of The Musculoskeletal Association of Chartered Physiotherapists

Manual Therapy 16 (2011) 609–613

Contents lists available at ScienceDirect

Manual Therapy

journal homepage: www.elsevier.com/math

Original article

# The immediate effect of unilateral lumbar Z-joint mobilisation on posterior chain neurodynamics: A randomised controlled study

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## ARTICLE INFO

*Article history:*
Received 3 August 2010
Received in revised form
21 April 2011
Accepted 13 June 2011

*Keywords:*
Manual therapy
Posterior chain flexibility
Neurodynamics
Joint mobilisation

## ABSTRACT

Hamstring strain (HS) is a common musculoskeletal condition and abnormal neurodynamics has been shown to influence HS and delay recovery. The efficacy of stretching for preventing and treating HS remains uncertain despite extensive research and wide-spread use. The effects of cervical spine mobilisation on peripheral nervous system function, neurodynamics and muscle force in the upper limb have been reported. Very few studies have reported effects of lumbar spine mobilisation on these variables in the lower limb. This study aimed to determine immediate effects of either a unilateral zygopophyseal joint posteroanterior mobilisation or a static posterior chain muscle stretch on the range of passive straight leg raise (SLR) in comparison to a non-treatment control. Using a single-blinded, randomised controlled study design, 36 healthy participants were allocated into one of three groups (control; mobilisation; static posterior chain muscle stretch). Measures of SLR were taken before and after intervention for each group on the day of testing. A General Linear Model (GLM) and a paired sample *t*-test showed a significant difference between base line and post-intervention for the mobilisation group only ($p < 0.001$), and suggests that unilateral lumbar spine zygopophyseal joint mobilisation can immediately restore posterior chain neurodynamics.

## 1. Introduction

Hamstring strain injuries comprise a significant proportion of acute musculoskeletal injuries within the sporting population, ranging from recreational to elite and professional level athletes (Marshall et al., 2007; Shankar et al., 2007). It has been repeatedly observed that athletes involved in explosive power events such as rugby or track events are highly prone to hamstring strains due to the rapid contract-relax demands that sprinting places on muscles of the posterior chain (Bennell and Crossley, 1996; Hawkins et al., 2001). For the purpose of this paper, the term “posterior chain” refers to muscles and neural structures of the posterior hip, thigh and lower leg. In sprinting type sports the majority of hamstring injuries occur during terminal swing (Garrett, 1996; Orchard, 2002), usually within an intramuscular tendon and adjacent muscle fibres (Koulouris and Connell, 2003; Askling et al., 2007a). Dancers are also at risk for hamstring and other posterior chain muscle strains, however, the mechanism of injury appears to be due to the extreme stretch placed on the muscle and tendinous tissue, commonly through a combined hip flexion and knee extension movement. Dance injuries appear to be independent of speed and typically present within the semimebranosis and its proximal free tendon, subsequently requiring significant healing time and extending the convalescent period for the athlete (Askling et al., 2007b).

Debate exists regarding the efficacy of skeletal muscle stretching programs on tissue injury prevention, with a large proportion of this relating to hamstring strain prevention and healing (Weldon and Hill, 2003; Arnason et al., 2008). One popular contemporary theory for explaining the mechanism of action through which stretching may allow an increase in tissue extensibility is the “sensory theory”. This theory postulates that increases in tissue extensibility do not come from affecting the mechanical properties of the muscle but are the result of changes in the individuals perception of the specific sensation e.g. stretch or pain (Weppler and Magnusson, 2010). Despite this theory and several others, a proven explanation for the mechanism of action for stretching does not exist. In addition, the optimal dose and method of stretching remains unclear despite suggestions for these variables being important for injury prevention (Dabedo et al., 2004). This is largely due to a lack of homogeneity in the research combined with

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doi:10.1016/j.math.2011.06.004

poor methodological quality. It is however accepted that once a hamstring injury has been sustained, a high re-injury rate exists, with the etiology of the injured muscle including weakness, residual fibrotic changes leading to reduced extensibility, as well as adverse adaptive biomechanics and motor recruitment patterns during sporting movements (Orchard and Best, 2002).

Current literature on prevention and rehabilitation of hamstring injury proposes arguments for attention to local muscular as well as lumbopelvic function. For instance, Brockett et al. (2001) stress the importance of a program of eccentric hamstring exercises to shift peak force development towards longer musculo-tendon lengths. Conversely, Sherry and Best (2004) advocate the restoration of neuromuscular control and normal movement patterns in the lumbopelvic region, and Orchard et al. (2005) subsequently identified that neuromuscular control in this region is required to enable optimal hamstring function during sporting activities.

Abnormal neurodynamics is one factor that could influence both hamstring muscle activity as well as lumbopelvic biomechanics (Turl and George, 1998), and in this region could be referred to as posterior chain neurodynamics. Neurodynamics is the term used to describe the integrated morphological, biomechanical and physiological functions of the nervous system (Butler, 2000; Shacklock, 2005, 1995). Changes in posterior chain neurodynamics and their influence on resting muscle length can be clinically measured using the passive straight leg raise test (SLR) (Boyd et al., 2009). Boyd et al. (2009) further showed that ankle dorsiflexion (plantar grade), but not ankle plantarflexion, can affect posterior chain neurodynamics, in turn decreasing SLR angle through triggering protective muscle spasm.

If an individual with posterior chain muscle injury presents clinically with abnormal neurodynamics in the nerves that innervate those muscles, preliminary research has suggested that neural mobilisation exercises could reduce the rate of re-injury (Turl and George, 1998). In addition to this, Dishman and Bulbulian (2000) investigated the immediate effect of lumbar spine mobilisation on efferent responses and subsequently described lower limb motor neuron inhibition. Recently, it has been found that grade III mobilisations (large amplitude movement moving into resistance) delivered unilaterally to lumbar spine Z-joints at a frequency of 2Hz induces sympathetic nervous system (SNS) changes (determined by measuring skin conductance) in the lower limb in a manner specific to the side of the spine receiving treatment (Perry and Green, 2008). Despite these, few studies have investigated the relationship between lumbar spinal mobilisation and lower limb neural activity either afferent or efferent. Models of this relationship have however been studied in other spinal regions. In the cervical spine, for example, Vicenzino et al. (1998) and Sterling et al. (2001) report spinal mobilisation techniques produce peripheral neurophysiological effects such as hypoalagesia and sympathoexcitation changes. Also, Coppieters et al. (2003) demonstrated changes in aberrant protective force generation in the upper limb, following cervical spine mobilisation.

This initial study aimed to explore the effect of lumbar spinal mobilisation on a gross measure of posterior chain neurodynamics (SLR), and specifically investigated the hypothesis that unilaterally delivered PA-mobilisations at the rate of 2Hz to the lumbar spine Z-joints would produce a greater immediate Ipsilateral increase in SLR (with ankle plantar grade) than that of a ipsilateral static posterior chain muscle stretch or control treatment.

## 2. Methodology

### 2.1. Participants

A power study was conducted using G-Power Version 3.0.8 (http://www.psycho.uni-duesseldorf.de/aap/projects/gpower/). For a 5% significance level, a default ‘medium’ effect size 0.25 and power 80%, the sample size required was 36 participants (12 per sample group). 19 males and 17 females between 18 and 65 years of age (mean 37.28 years; SD 12.370) were recruited. Recruitment was achieved through information flyers at a physiotherapy private practice, a University and local running clubs. None of the participants in the study were existing patients of the private practice. All volunteers were further assessed for their suitability using exclusion criteria; participants scoring more than 70° for an SLR test were excluded (to prevent the lumbar or sacroiliac region from limiting hip range of motion (ROM) [Magee, 2008]). Participants who produced a positive hip quadrant test were also excluded (to eliminate the influence of hip joint pathology on the test) as were participants with a reported history of spinal surgery or severe spinal/back injury. Based on the concealed, third party randomization method described by Schulz et al. (1995) (using opaque, sealed, numbered envelopes prepared from random number tables), participants were randomly allocated into one of three groups. Ethical approval was obtained from the relevant University Human Research Ethics Committee. All volunteers received written information with verbal explanations and gave written informed consent prior to the experiment.

### 2.2. Repeatability study

A repeatability study was performed on the determination of the first point of detected limb resistance (R1) in the SLR test. This involved a full replication of the measurement procedure (see “Research method and experimental interventions”). The SLR test was performed 3 times each on 7 participants; the SLR device was then removed during a 3 min break, then the device was reapplied and the SLR test was performed 3 more times on the 7 participants. During each replication, researcher 1 stopped the movement of the tested limb at R1, and the range of hip flexion (degrees) was recorded by researcher 2. Researcher 1 was blind to the angular measures on each replication. To determine the repeatability of researcher 1’s detection of R1, Intraclass Correlation Coefficients (ICC) were calculated. For the initial 3 SLR measurements of each participant, the ICC was 0.982 (confidence interval 0.934, 0.997) and for the final 3 SLR measurements, the ICC was 0.974 (confidence interval 0.906, 0.995). Both of these ICC’s indicate a high degree of reliability between the SLR measurements, and therefore the repeatability of researcher 1’s detection of R1.

### 2.3. Research design

A single-blind randomised controlled research design was used, with each participant being randomly allocated to either the *control group*, treatment group 1 (*mobs group*) or treatment group 2 (*stretching group*). Three researchers were involved in the data collection of this study. Researcher 1 applied the equipment and performed the SLR. Researcher 2 recorded the angle of hip flexion reached (i.e. SLR angle) and researcher 3 applied one of three interventions. All of the interventions were undertaken in a private room with only researcher 3 present, thus blinding researchers 1 and 2 to the interventions being undertaken, thereby eliminating potential bias. Successful blinding was ensured as no communication occurred between researchers 1 and 3 or researchers 2 and 3.

### 2.4. Research method and experimental interventions

An SLR device was used in this study to control joint position during the testing. The device maintained the knee in full available extension and the ankle in plantar grade which standardized limb positioning whilst “preloading” neural structures in the posterior chain (Boyd et al., 2009). Hip ROM (flexion) was measured in degrees relative to the horizontal with a bubble inclinometer attached to the SLR device.

The experiment took place in a private air-conditioned room with the temperature thermostat set at 23° to standardize treatment conditions. Participants were positioned in supine on the treatment plinth in a standardized position, with the non-tested leg strapped to the plinth mid way between the greater trochanter and head of the fibula. Researcher 1 attached the straight leg raise device to the tested limb and then the limb was raised into hip flexion and movement was controlled to the sagittal plane. Limb movement was stopped at R1 as detected by researcher 1 (whose repeatability of this measure has been reported earlier). R1 was thought to represent protective muscle spasm in the posterior chain muscles due to increased neural stress induced through positioning the ankle in plantar grade (Boyd et al., 2009). The angle of SLR was then measured by researcher 2 by reading the inclinometer on the SLR device (degrees) (see Fig. 1). Once recording of this range of motion was complete, researcher 1 returned the limb to the plinth. This measurement process was performed another two times (three times in total), and the results of the three replications were subsequently averaged during data analysis. Researchers 1 and 2 left the treatment room and researcher 3 entered. Researcher 3 then applied one of the three randomised intervention conditions and then left the room. Researchers 1 and 2 returned to the treatment room and repeated the measurement protocol described above. The intervention conditions were one of the following:

- *Control group* (CG) – the participant lay in supine for 3 min (in the presence of researcher 3)
- *Mobs group* – unilaterally applied grade III oscillatory PA-mobilisations at a frequency of 2 Hz to the T12/L1, L1/L2, L2/L3, L3/L4, L4/L5 and L5/S1 Z-joints for 30 s per joint (3 min total treatment) on the ipsilateral side to the tested leg. Due to the preliminary nature of this study, all lumbar spine levels were mobilised in an attempt to provide a greater treatment dose than if just one single spinal level were chosen. Furthermore, the SLR test may examine neurodynamics of neural tissue originating from multiple spinal level segments, thus mobilising a single spinal segment could reduce the magnitude of possible effects. The rationale for mobilising each segment for 30 s was to standardize the treatment and to make the total treatment time for the *mobs group* (3 min) equal to group 2.
- *Stretching group* – a static stretch of the muscles of the posterior chain (on the ipsilateral side to the tested leg) for 3 min at the point of R1 as determined by researcher 3. For this intervention, the limb was moved into the stretching position as per the SLR testing protocol with the knee maintained in full available extension and the ankle in plantar grade to ensure standardization of interventions. It must be noted that for the interventions performed on group 2, R1 was determined by intervention researcher 3 (not the measuring researcher 1 as per the SLR testing protocol). This stretching protocol was employed due to its frequent use in the sporting and general populations.

**Fig. 1.** Straight leg raise measuring.

Each intervention lasted for 3 min in total to ensure matching of the intervention doses.

### 2.5. Data analysis

As there were 3 groups (*control group*, *mobs group* and *stretching group*) over 2 time periods (pre- and post-intervention), a General Linear Model (GLM) was used to determine if there were any significant differences. If the *p*-value was less than 0.05, post-hoc tests would be used to determine where the difference(s) lay.

## 3. Results

### 3.1. Homogeneity of matched groups

All 36 participants completed the study (12 per group). The *control group* consisted of 6 males and 6 females; *mobs group* consisted of 7 males and 5 females; *stretching group* consisted of 6 males and 6 females (see Table 1). A one-way ANOVA revealed that the 3 groups did not differ for participant weight and height measures. However, the *control group* differed in age (younger) from the *mobs group* and the *stretching group* (see Table 1). Further participant comparability was shown by constructing a clustered boxplot displaying pre-intervention and post-intervention SLR measures (in degrees) for each experimental group. Boxplot overlap for each group's pre-intervention SLR measure suggested the groups were not significantly different for this parameter at base line (see Fig. 2).

### 3.2. Ipsilateral SLR by group and time

The GLM of the independent measure (SLR) for group and time (pre- and post-intervention) was significant ($p < 0.001$). A post-hoc test revealed that the only group that differed between the two measurement periods (pre- and post-intervention) was the *mobs group* ($p < 0.001$) (see Table 2). This result is graphically demonstrated in Fig. 2.

**Table 1**
Anthropometric data of subjects in each experimental group.

| Measure | All subjects (19M, 17F) | Control group (6M, 6F) | Mobs group (7M, 5F) | Stretching group (6M, 6F) |
|---|---|---|---|---|
| Weight [Mean (SD)] | 70.89<br>(10.748) | 71.25<br>(13.081) | 71.58<br>(8.867) | 69.83<br>(10.769) |
| Age [Mean (SD)] | 37.28<br>(12.370) | 30.42<br>(7.657) | 40.25<br>(15.452) | 41.17<br>(10.582) |
| Height [Mean (SD)] | 172.22<br>(7.826) | 173.33<br>(5.990) | 172.58<br>(9.846) | 170.75<br>(7.629) |

SD: standard deviation; Weight: kilograms; Age: years; Height: centimeters; M: male; F: female.

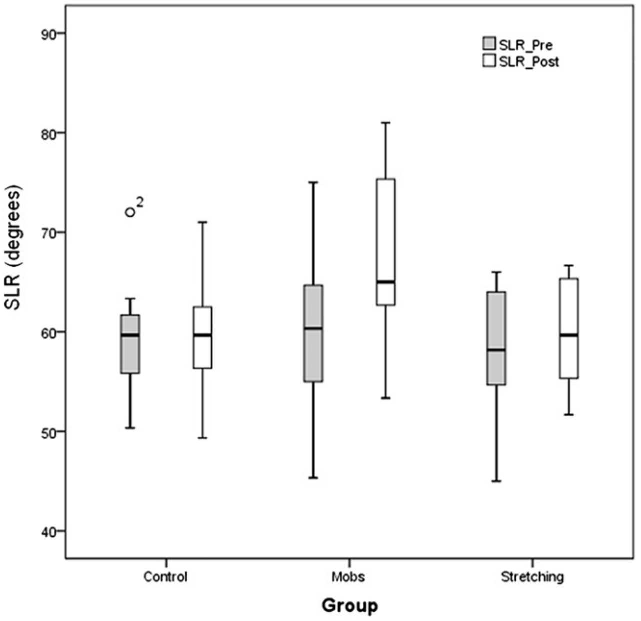

**Fig. 2.** Clustered boxplot comparing pre-intervention and post-intervention (left and right respectively) SLR measures for each experimental group.

## 4. Discussion

The results of this study showed that unilaterally applied grade III oscillatory PA-mobilisations at a frequency of 2 Hz to the T12/L1, L1/L2, L2/L3, L3/L4, L4/L5 and L5/S1 Z-joints for 30 s per joint (3 min total treatment) resulted in an immediate increase in mean SLR measure (on the ipsilateral side to the treated Z-joints) post-intervention, when compared with the pre-intervention (baseline) mean SLR measure. This result was significant and due to the recent findings of Boyd et al. (2009) most likely reflects a change in posterior chain neurodynamics. The participants in each experimental group of this study were matched for gender, height and weight measures; however the *control group* was younger in age than the *mobs group* and *stretching group*. In considering that there was no significant difference in results between the *control group* (no intervention) and the *stretching group*, this finding may indicate that age was not an important factor affecting SLR. Current literature on spinal mobilisation and its effects on the lower limb are sparse; however Perry and Green (2008) showed that unilateral lumbar spine mobilisation can induce side specific changes in lower limb SNS activity. Dishman and Bulbulian (2000) have also shown that both spinal manipulation with thrust and spinal mobilisation without thrust, induced transient alpha motor neuron inhibition in the motor neuron pool (tibial nerve region) supplied by the treated spinal segments. The current study seems supported by the findings of Dishman and Bulbulian (2000), as the SLR measures were increased in the *mobs group* post mobilisation intervention, and that such effects have been shown by electromyography to correspond with decreased posterior chain muscle activity (Boyd et al., 2009). Whilst the SLR measure increased ipsilateral to the side receiving treatment, this study did not examine the effect of unilateral lumbar spine mobilisation on contralateral SLR measurements. From a clinical perspective, this may allow a therapist to physically treat the non-painful side of a patient's body whilst achieving treatment effects on the contralateral painful side, and thus should be investigated in future studies. Additionally, this study applied a multiple spinal segment treatment approach, as opposed to mobilising a single specific spinal segment, more common in clinical practice. Whilst this broad approach was chosen to satisfy the explorative nature of this study, future studies investigating the effects of specific segmental lumbar spine mobilisation on SLR measures (ipsilateral and contralateral) are recommended. Further investigation is also required for determining the optimal dose of treatment. This study used 30 s per spinal segment (3 min total treatment), which produced an effect on SLR, however shorter or longer doses may have produced varying results. From a clinical perspective, knowledge of the most effective dose of treatment would be of great relevance.

**Table 2**
Paired sample *t*-test (post-hoc).

| Group | *N* | Mean degrees pre (SD) | Mean degrees post (SD) | Diff mean | *p*-value |
|---|---|---|---|---|---|
| Control group | 12 | 59.47 (5.402) | 59.58 (5.452) | 0.111 | 0.746 |
| Mobs group | 12 | 59.69 (7.730) | 68.19 (8.722) | 8.500 | 0.000 |
| Stretching group | 12 | 58.42 (6.415) | 59.97 (5.540) | 1.556 | 0.056 |

Mean pre: average of degrees for the SLR recorded before experimental intervention; Mean post: average of degrees for the SLR recorded after experimental intervention; SD: standard deviation; Diff mean: differences between means.

The non-significant result for the *stretching group* in this study was in agreement with the findings reported in the literature. The efficacy for static muscle stretching (particularly of posterior chain muscles) to increase tissue extensibility has not been proven despite extensive research (Weldon and Hill, 2003; Arnason et al., 2008). Furthermore, R1 in this study was not determined by the participant but by the researcher and this would have reduced the potential for changes in participant perception of muscle stretch over the course of the study to influence results (Weppler and Magnusson, 2010) obtained for the *stretching group*. Due to the preliminary nature of this study, further research is needed to confirm the significant findings of this study relating to the *mobs group* and the non-significant findings pertaining to the *stretching group*. The null affect for the *control group* was expected as participants from this group received no intervention. To the author's knowledge, this preliminary study is the first to investigate the effects of lumbar spine mobilisation on range of SLR. A limitation of the current study lies within the use of the SLR measure as the only outcome measure, future studies may also include the use of electromyography as employed by Boyd et al. (2009).

The mechanism of action for the measured increase in SLR is currently unknown, as is the mechanism by which spinal mobilisation induces SNS changes in the lower limbs (Perry and Green, 2008). Investigation into the mechanism of spinal mobilisation affecting SLR, and potentially neurodynamics, was beyond the scope of this study, however research into this area is recommended. Added studies in the future should then research the role of spinal mobilisation techniques for treating abnormal neurodynamics in athletic populations, specifically in relation to hamstring strain prevention and recovery.

## 5. Conclusion

The results of this preliminary study indicate that unilaterally applied grade III oscillatory PA-mobilisations at a frequency of 2 Hz to the T12/L1, L1/L2, L2/L3, L3/L4, L4/L5 and L5/S1 Z-joints for 30 s per joint cause an immediate increase in SLR, ipsilateral to the side treated. This outcome likely reflects a change in posterior chain neurodynamics. Additionally, this study revealed that static stretching of the posterior chain muscles with the ankle locked in plantar grade did not affect ipsilateral SLR. Future studies should examine the affect of unilateral lumbar spine mobilisations on contralateral SLR, as this could potentially allow a clinician to physically treat the non-symptomatic side of a patient's body whilst achieving treatment effects on the contralateral symptomatic side.

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