Decreased tibial nerve movement in patients with failed back surgery syndrome and persistent leg pain.

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Abstract

Purpose To measure and compare the total and normalised tibial nerve movement during forward bending in patients with and without Failed Back Surgery Syndrome(FBSS) and persistent leg pain following anatomically successful lumbar decompression surgery and demonstrated no psychological stress. Nerve pathomechanics may contribute to FBSS with persistent leg pain following anatomically successful lumbar decompression surgery.

Methods Tibial nerve movement during forward bending was measured in two groups of patients following anatomically successful lumbar decompression surgery. FBSS group(N=37) consisted of patients with persistent leg pain following lumbar surgery and non-FBSS(N=37) were patients with no remaining leg pain following lumbar surgery. Total and normalised tibial nerve movement at the popliteal fossa was measured by a previously validated ultrasound imaging technique and compared between the two groups, and also between the painful and non-painful leg within the FBSS group.

Results Both the mean total and normalised tibial nerve movement were significantly decreased in the FBSS group in both legs when compared to the non-FBSS group ($P<0.05$). The total and normalised tibial nerve movement was also more restricted in the painful leg($P<0.05$) when compared to the non-painful side within the FBSS group.

Conclusion This was the first study to quantify the decreased total and normalised tibial nerve mobility in FBSS patients with persistent leg pain when compared with non-FBSS patients following anatomically successful lumbar decompression surgery. Further research could investigate the efficacy of intervention, such as nerve mobilisation in this particular group of patients with failed back surgery syndrome and limited nerve mobility.

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Keywords:

Failed back surgery syndrome; neuropathic pain; sciatica; nerve movement; post-operative pain.

Introduction

Lumbar surgery is performed on approximately 23,592 patients each year in the United Kingdom[1]. However, it is estimated that 10-40% of these patients will continue to experience pre-surgical symptoms and pain despite anatomically successful surgery for either lumbar intervertebral disc disorder[2] or lateral recess syndrome[3]; a condition referred to as Failed Back Surgery Syndrome (FBSS)[4]. A recent study estimated the incidence of FBSS at 20.8% within 2 years of lumbar surgery[1], although incidence levels vary across surgical procedures, with rates of 35-36.2% reported following lumbar decompression[5] and a rate of 20-25% reported following lumbar microdisectomy[6]. FBSS results in continued pain, functional limitations and reduced ability to work[1], with FBSS patients with persistent leg pain reporting much lower health-related quality of life scores(EQ-5D scores of 0.16 ± 0.3) than other causes of neuropathic pain[4]. FBSS results in significantly increased post-surgical healthcare costs that are estimated to be over 50% greater than lumbar surgery patients with no continued pain[1]. Furthermore, FBSS exacts a high societal cost with up to 15% of young, active participants failing to return to work despite having no overt re-herniation or lumbar pathology post-microdiscectomy[7].

Nerve root impingement resulting in peripheral nerve pain is a common characteristic of both intervertebral disc disorder and lateral recess syndrome. Peripheral nerves such as the tibial nerve must bend, stretch and glide along their length within the nerve tissue bed to accommodate movement of the adjacent joints whilst maintaining the transmission of electrical impulses[8]. Nerve root impingement could compromise the ability of a peripheral nerve to stretch and glide causing reduced neural mobility and subsequent increased neural tension and associated loss of function, pain or neural fibrosis[9], increased mechanosensitivity[10], a reduction in nerve conduction, inhibited axonal transportation and neural oedema[11].

An innovative technique was developed to measure tibial nerve movement at the knee during forward bending movement of the spine[12]. During forward bending, a mean tibial nerve movement of 12.2 ± 2.2mm measured at the popliteal fossa was found in asymptomatic participants, which has been shown to be a reliable measurement[12]. The substantial proximal movement of the tibial nerve during forward bending is consistent with the requirement of the nerve tract to accommodate increases in the nerve bed length evoked by hip and lumbar spine flexion [12]. It was hypothesized that reduced nerve movement could potentially contribute to the persistent leg pain of FBSS.

The aim of this study was to compare both the total and normalised tibial nerve movement between FBSS and non-FBSS patients following lumbar surgery, and between the painful and non-painful leg within the FBSS group. It was hypothesised that people with FBSS and persistent leg pain will present with reduced total and normalised tibial nerve movement when compared to people without persistent leg pain following lumbar surgery. A second hypothesis was that there would be significant differences in the tibial nerve movement between the painful and non-painful side in people with FBSS.

Materials and Methods:

Ethical Approval

Ethical approval was granted by the National Health Service (NHS) Health Research Authority, United Kingdom. A total of seventy-four patients with and without post-operative leg pain following discectomy or lumbar decompression were recruited.

Sample Size

Our previous work has shown that during forward bending in 24 asymptomatic participants the sciatic nerve moves at the popliteal fossa by 12.2 ± 2.2 mm[12]. However, no data regarding nerve movement in symptomatic participants has been previously published. Based on a 15% difference in the tibial nerve movement between the FBSS and non-FBSS group following lumbar surgery and the observed standard deviation of 2.2mm at 95% power and 5% alpha, 32 participants per group was required in this study.

Participants

People with (N=37) or without (N=37) postoperative residual leg pain following lumbar discectomy or decompression completed this study with the following eligibility criteria:

Inclusion criteria:

Patients aged 18-80 years who underwent lumbar microdiscectomy or single level lumbar decompression surgery, 6-12months post-operation.

Patients who have persistent postoperative residual leg pain as defined by:

a) The severity of leg pain score being 5 or more on Numerical Rating Scale of Pain[13].
b) less than 5 points improvement in the Global Rating of Change Scale, in which a clinically important improvement is defined as 5 or more[14].
c) a positive straight leg raise (SLR) sign (specified as 65° or less movement of the straight leg relative to the longitudinal axis of the trunk) that the test reproduced unilateral symptoms in the tested leg[15].

Exclusion Criteria:

Participants were excluded if they suffered from long standing ischaemic neuritis or any other surgery-related complications (e.g. inadequate decompression, postoperative instability, neural injury) as they may lead to postoperative residual leg pain. Patients were also excluded if identified as at risk by the Distress and Risk Assessment Method(modified Zung score ≥ 17 and/or Modified Somatic Perception Questionnaire score < 12)[16], which has been shown to be an accurate assessment tool of psychological disturbance in patients with low back pain[16].

Seventy-four patients were recruited for the study in accordance with the eligibility criteria. Participants were divided into two groups dependent on surgical outcomes:

Non-FBSS group (N=37): Participants with no or minimal residual leg pain during forward bending; defined as (A) greater than 50% improvement three months after the operation, and (B) a negative straight leg raise sign when the maximum angle between the straight leg and the longitudinal axis of the trunk is 66° or more[17].

FBSS group (N = 37): Participants with post-operative residual leg pain during forward bending; defined as (A) either unchanged or less than 50% improvement three months after operation as defined on a visual analogue scale; and (B) a positive straight leg raise sign when the maximum angle between the straight leg and the longitudinal axis of the trunk is 65° or less, with unilateral symptoms reproduced in the tested leg[17].

Subjects were assessed at the Spinal Unit of a local hospital on one occasion, three to nine-months post-surgery with the following outcome measures:
Ultrasound recordings of linear arrays centre frequency at 7.5Mhz (Model: HL5-9ED, Medison Co., Ltd, Seoul, South Korea) during forward bending were taken behind the knee region in order to track movement of the tibial nerve using a similar technique developed from previous research[12, 18]. The image sequences of the diagnostic ultrasound cine-loops were analysed using a frame-by-frame normalised cross-correlation approach implemented in MATLAB (MathWorks, Natwick, MA, USA) [12]. The tracking programme used a pattern-matching algorithm based on the greyscale pattern present in each of the selected region of interests to find the best match region of interests in sequential frames. Displacement of the nerve in the longitudinal (lateral) and axial (deep/superficial) dimensions were registered for each frame-by-frame matching comparison. The programme then calculated the hypotenuse excursion from the vector combination of longitudinal and axial movement.

Spinal and hip movements were measured within physiological ranges. Lumbar spine and hip movement and coordination were measured using the three-dimensional inertia measurement unit (ProMove 3D, Inertia Technology, The Netherlands) during the forward bending movement. From an erect standing position, participants were instructed to bend forward as far as comfortably possible at their natural and controlled pace to reach their maximum forward bend angle. The erect start position had the participant standing tall, looking straight ahead with arms folded across their chest, feet positioned shoulder width apart. Three bending forward movements were recorded with a rest period of 2 min between each movement[12]. Markers were placed on 4 standardised landmarks on the posterior thigh, sacrum and L1 spinous process. Signals were Analog to Digital converted (200Hz sampling frequency) and stored for offline analysis.

The tibial nerve movement(displacement) was then normalised by dividing it by the sum of the lumbar spine and hip flexion angles during each forward bending movement: Normalised tibial nerve movement (mm/º) = Tibial nerve movement (mm) / Total lumbar spine and hip flexion angle (º)

To minimize bias, the researcher was blinded to each participant's information or grouping during offline data analysis.

The improvement between before and after surgical intervention was measured with the Global Rating of Change Scale with a 15-point scale (-7 to +7), in which a clinically important improvement was defined as 5 or more[14]. Participants were asked to rate their severity of back pain and leg pain using a simple 10cm visual analogue scale[19]. A standardized passive straight leg raise (SLR) test was performed and the maximum angle between the straight leg and the longitudinal axis of the trunk measured using an inclinometer. SLR sign was considered to be positive if the lift angle was 65° or less, with unilateral symptoms reproduced in the tested leg[17].

The level of psychological stress was measured by the Distress and Risk Assessment Method[16], which is a combination of the Modified Zung depression scale and the Modified Somatic Perception Questionnaire to assess depression and somatisation of anxiety. The threshold scores in the Distress and Risk Assessment Method has been validated in identifying psychological disturbance in patients with low back pain[16].

Statistical analyses

Descriptive statistics were produced of the mean and standard deviation of the angle of SLR and longitudinal, axial and hypotenuse nerve excursion magnitude. Statistical analysis was performed with SPSS software (Version 22.0). Intra-class correlation coefficient ($ICC_{3,k}$) with 95% confidence interval was calculated to determine intra-rater reliability of the three repeat measures of forward bending.

The Kolmogorov-Smirnov test ($p=0.065$) concluded that the data is homogeneous, parametric statistical tests were therefore conducted with the level of significance set at 0.05.

T tests were used to compare the statistical differences in the tibial nerve movement between FBSS and non-FBSS group of the painful side and non-painful side. T-tests were also used to compare the clinic outcome measures between the non-FBSS and FBSS groups.

Paired T-test was used to compare the tibial nerve movement between the painful leg and the non-painful leg within each group (FBSS or Non-FBSS).

Results

Subject characteristics were presented in table 1. No participants dropped out of the study during the one-off assessment.

There were no significant differences in the scores of the Modified Zung depression scale and Modified Somatic Perception Questionnaire between non-FBSS group and FBSS group. All participant have a modified Zung depression score less than 17 and no participant has a Modified Somatic Perception Questionnaire score less than 12.

The angle of SLR was significantly more limited in FBSS group (42.0° ± 16.2°) when compared to non-FBSS group (76.5° ± 7.0°) (Table 1, $P < 0.05$).

During the forward bending movement, the flexion range of movement of the lumbar spine and hip were significantly reduced in FBSS group when compared with the non-FBSS group (Table 1, $P < 0.05$).

The mean $ICC_{3,k}$ for measuring the normalised longitudinal, axial and hypotenuse movement of the tibial branch of sciatic nerve were found to be 0.947, 0.908 and 0.956 respectively on the non-painful side and 0.991, 0.985 and 0.992 respectively on the painful side.

During the forward bending movement, both the total and normalised tibial nerve movements in the longitudinal, axial and hypotenuse planes were significantly reduced in the painful in the FBSS group when compared to the non-FBSS group (Table 2, $P < 0.05$). There were also significant reduction in the total and normalised tibial nerve movements in the non-painful side in the FBSS group when compared to the non-FBSS group (Table 2, $P < 0.05$).

Within the non-FBSS group, there were no significant differences in the total and normalised tibial nerve movement between painful and non-painful side during forward bending (Table 2, $P > 0.05$).

Within the FBSS group, the total and normalised movements of the tibial nerve were significantly reduced in the painful leg when compared to the non-painful leg (Table 2, $P < 0.05$) during the limited forward bending movement of both the lumbar spine and hips (Lumbar flexion: 26.6° ± 5.3°; Hip flexion: 17.2° ± 4.2°).

Discussion

Despite anatomically successful lumbar decompression surgery, FBSS is estimated to occur in 20.8% of patients within 2 years of surgery[1] and is a significant problem to patients, healthcare providers and society. Further understanding of neural pathomechanics and any involvement in FBSS will potentially contribute to the development of an appropriate intervention for this problematic condition. Consequently, this study examined nerve pathomechanics in two groups of post-lumbar surgical patients; one group with successful clinical outcome (non-FBSS) and the other group with FBSS presenting with persistent leg pain following successful anatomical decompression. Tibial nerve movement during forward bending was compared between the two patient groups, and between the painful and non-painful leg in the FBSS patients, using the previously validated ultrasound imaging technique. This is the first study involving non-invasive in-vivo measures of the magnitude or timing of strain occurring in the tibial nerve during spinal and hip movements in FBSS and non-FBSS patients following lumbar decompression.

The observed total movement of the tibial nerve in non-FBSS patients is consistent with the requirement of the nerve tract to accommodate increases in the nerve bed length evoked by hip and lumbar spine flexion during forward bending identified in previous studies[12]. In the FBSS group, the reduced total and normalised tibial nerve excursion could potentially cause increased nerve tension leading to loss of function and pain[9], as demonstrated in the results of this study. Nerve root restrictions can lead to distal alterations in sciatic nerve movement and strain during forward bending as this section of the nerve tract is forced to accommodate more changes in nerve bed length, a finding observed in animal and cadaveric studies[20]. However, it could be expected that the elimination of nerve root impingement following decompression lumbar surgery would result in the return of normal peripheral nerve movement. All patients with remaining residual pain had a post-operative MRI which failed to identify any remaining restrictions of the nerve root in the lumbar spine. Consequently, it is hypothesised that the persistent postoperative leg pain could be caused by tightening and/or shortening of the sciatic/tibial nerve due to prolonged movement restrictions prior to surgery. If the persistent pain is at least partly due to decreased nerve movement, this could potentially be resolvable with appropriate post-surgical treatment. Persistent post-operative neuropathic pain could also be caused by initial nerve damage, which could lead to permanent neural symptoms with minimal improvement of symptoms expected.

People with failed back surgery syndrome have been reported to suffer for an average of 4.7 years[21]. Prolonged nerve root compression has been shown to cause inflammatory changes to the nerve fibres that can result in perineural scarring, nerve fibrosis and intraneural oedema[22]. These changes can result in shortening and tightening of the nerve which subsequently affect neural biomechanical properties[23], leading to mechanosensitivity symptoms including a painful response to nerve stretch during joint movements[10]. Following successful lumbar decompression surgery, it is hoped that normal nerve mechanics will be restored, however, in some instances it appears that this fails to happen. It is proposed that persistent altered nerve mechanics could be responsible for the limited range of motion observed at the lumbar spine and hip in the FBSS patients, which subsequently lead to other nerve changes that produce long term neuropathic pain. Within the FBSS group, both the total and normalised tibial nerve movement was significantly reduced in the painful leg compared with the non-painful leg at the same limited forward bend position. However, the straight leg raise angle of the non-painful leg was negative (greater than 65 degrees) indicating there was no movement restriction of the sciatic/tibial nerve in the non-painful leg, implying that the limiting factor of the lumbar spine and hip movement was the altered nerve mechanics in the painful leg. A decrease in the ability of peripheral nerves to bend, stretch and glide may limit the transmission of electrical impulses[8] and the dispersion of intraneural fluid[24]. Such limited nerve movement may cause the persistent leg pain in the FBSS group as observed in this study.

It is well recognised that biological, psychological and social factors can all be influential in the development of low back pain with non-specific low back pain defined as low back pain that cannot be attributed to a specific pathology [25]. Psychological interventions have been shown to be beneficial in the management of idiopathic chronic low back pain in patients who do not have surgically remediable pathology. The Distress and Risk Assessment Method (DRAM) has been shown to be an effective tool for identifying patients that will benefit from psychological intervention[16]. Both patient groups in this study demonstrated no significant differences in both Zung Self-Rating Depression Scale and Modified Somatic Perception Questionnaire which are part of DRAM assessment suggesting that the FBSS patients with chronic persistent postoperative leg pain of this study were not indicated for any psychological interventions. This implies that the persistent leg pain of the FBSS patient group was unlikely to be associated with psychosocial factors but rather due to a mechanical cause such as altered nerve biomechanics. Further research could investigate potential causes of the observed restricted neural mobility including the influence of pain, and whether removal of pain via a spinal nerve block may result in improved neural mobility in patients with persistent leg pain of FBSS. Further research could also investigate the efficacy of intervention, such as nerve mobilisation in this particular group of patients with failed back surgery syndrome and limited nerve mobility.

The limitation of this study was that the assessor was not blinded to the grouping of the participants during the clinical assessments and ultrasound recordings as it was obvious that the participants in the FBSS group with persistent leg pain would normally present with a more limited lumbar and hip movement and limited straight leg raise angle. However, the researcher was blinded to each participant's information or grouping during offline data analysis of the nerve movement data and spinal and hip movement analysis. Participants were also only assessed on one occasion, three to nine-months post-surgery. It was unknown if the participants in the FBSS group with persistent leg pain would have improved their clinical and biomechanical outcome measures if reassessed over time.

Conclusion

This is the first study to compare the tibial nerve mobility evoked by forward bending in patients with and without failed back surgery syndrome following anatomically successful lumbar decompression and demonstrated no psychological stress.

Both total and normalised tibial nerve movements were significantly reduced in FBSS patients with persistent leg pain compared with non-FBSS patients following anatomically successful lumbar decompression surgery. In addition, the total and normalised tibial nerve excursion were also more significantly reduced in the painful leg when compared to the non-painful leg in FBSS patients with persistent leg pain.

Further research could investigate the efficacy of intervention, such as nerve mobilisation in this particular group of patients with failed back surgery syndrome and limited nerve mobility.

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List of tables

Table 1. Subject characteristics

	Non-FBSS	FBSS with Persistent leg pain
Age (years)	55.6 ± 13.2	54.4 ± 12.5
Height (cm)	169.3 ± 6.6	169.1 ± 7.1
Weight (kg)	73.7 ± 12.7	70.8 ± 9.7
Post operation days	146.1 ± 36.2	145.4 ± 36
Pre operation pain scale (Visual analogue scale(VAS))	8.7 ± 1.6	8.9 ± 1.1
Global rating of change scale (-7 to +7)	6.1 ± 2.1	2.2 ± 2.1 [a]
Severity of back pain (VAS)	0.3 ± 0.7	1.8 ± 3.1 [a]
Severity of leg pain (VAS)	0.8 ± 1.4	5.9 ± 1.8 [a]
Modified Somatic Perception Questionnaire	0.8 ± 1.6	1.2 ± 2
Modified Zung depression scale	6.1 ± 5.3	5.8 ± 4.4
Lumbar flexion during forward bending (°)	71.9 ± 8.2	26.6 ± 5.3 [a]
Hip flexion during forward bending (°)	29.2 ± 4.7	17.2 ± 4.2 [a]
Straight leg raise angle (painful side, °)	76.5 ± 7.0	42.0 ± 16.2 [a]
Straight leg raise angle (non-painful side, °)	77.6 ± 5.7	74.5 ± 12.8

[a] $P < 0.05$, significant differences in painful side between Non-FBSS and FBSS group (t test).

Table 2. Comparison between Non-FBSS group and FBSS group in the painful side of leg pain.

	Non-FBSS group		FBSS group	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
	Painful Side	Non-painful side	Painful Side	Non-painful side
Total Longitudinal tibial nerve movement (mm)	10.4 ± 2.1	11.3 ± 2.0	1.8 ± 0.7 [a]	3.8 ± 1.0 [b,c]
Total Axial tibial nerve movement (mm)	4.5 ± 0.5	3.7 ± 0.2	0.2 ± 0.1 [a]	1.2 ± 0.1 [b,c]
Total Hypotenuse tibial nerve movement (mm)	11.4 ± 1.9	11.9 ± 1.8	1.9 ± 0.7 [a]	4.1 ± 0.9 [b,c]
Normalized Longitudinal tibial nerve movement (mm/º)	0.1022 ± 0.0208	0.1114 ± 0.019	0.0411 ± 0.01075 [a]	0.0892 ± 0.023 [b,c]
Normalized Axial tibial nerve movement (mm/º)	0.0441 ± 0.005	0.0384 ± 0.0037	0.0043 ± 0.00502 [a]	0.0311 ± 0.011 [b,c]
Normalized Hypotenuse tibial nerve movement (mm/º)	0.1127 ± 0.0181	0.1186 ± 0.0178	0.0419 ± 0.01101 [a]	0.0946 ± 0.0228 [b,c]

[a] $P < 0.05$, significant differences in painful side between Non-FBSS and FBSS group (t test).
[b] $P < 0.05$, significant differences in the non-painful side between Non-FBSS and FBSS group (t test).
[c] $P < 0.05$, significant differences between painful and non-painful side within the FBSS group (paired t-test).