ORIGINAL ARTICLE

Assessment of Upper and Lower Limb Neural Tissue Extensibility in Asymptomatic Health Care Professionals

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ABSTRACT

Objective: To assess neural tissue extensibility of the upper and lower limb in asymptomatic healthcare professionals and to determine its association with work experience.

Study Design: Cross-sectional study.

Place and Duration of Study: The study was carried out at Fauji Foundation Hospital, Margalla Institute of Health Sciences, Pakistan Institute of Medical Sciences and Holy Family Hospital, Pakistan from 20th December 2024 to 4th August 2025.

Materials and Methods: A total of 384 asymptomatic healthcare professionals, aged 25–45 years were included, comprising physical therapists, dentists, and surgeons (128 participants from each category). The method of non-probability purposive sampling was applied. Upper and lower limb neural tissue extensibility was assessed using ULNT1, ULNT2, ULNT3 and slump test, prone knee bend test, and passive straight leg raise, respectively. Data were analyzed using descriptive statistics and spearman correlation to assess the relationship between work experience and neural extensibility via SPSS version 23.

Results: Among upper limb neurodynamics, median nerve showed highest positive response especially in dentists (Right: 35.9%, Left: 32%). While radial nerve depicted least positive response (10.4%) in all professionals. For lower limb neurodynamics, surgeons predominated in slump test results (Right: 22.7%, Left: 22.1%), while physical therapists showed the highest frequency for the passive straight leg raise (Right: 24.2%, Left: 21.1%). Moreover, work experience showed a statistically significant correlation ($p<0.05$) with neural tissue extensibility.

Conclusion: Occupational demands are associated with reduced neural tissue extensibility in healthcare professionals, particularly, dentists exhibited the greatest median nerve involvement, surgeons showed higher positive response in slump and prone knee bend tests and physical therapists demonstrated reduced extensibility in the passive straight leg raise test. These findings highlight the importance of early screening, ergonomic awareness, and preventive strategies in clinical practice.

Key Words: *Healthcare Professionals, Lower Extremity, Median Nerve, Neurodynamic Tests, Radial Nerve, Sciatic Nerve.*

Introduction

Healthcare professionals exposed to repetitive tasks and prolonged static postures may develop subclinical reductions in neural tissue mobility that remain undetected until functional impairment occurs. Although the human nervous system is designed to facilitate coordinated movement, prolonged or repetitive mechanical loading during professional activities may predispose peripheral nerves to dysfunction. These subclinical changes often manifest as a decrease in neural tissue extensibility, which can eventually hinder professional performance and lead to work-related musculoskeletal disorders (WMSDs).[1] WMSDs often progress through early stages of fatigue before resulting in a permanent reduction in work capacity.[2] Therefore, early detection of these neural changes is essential to prevent the transition from subclinical tension to chronic professional disability.[3]

Peripheral nerves are structurally designed to tolerate mechanical stress through protective

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connective tissue layers and organized fascicles. However, during routine activities, nerves are exposed to mechanical forces such as tension, compression, shear, and friction. When these forces exceed physiological limits or become prolonged, they may contribute to the development of peripheral neuropathies. Peripheral neuropathies are a major source of pain and functional limitation and are broadly classified into compressive and non-compressive types. Compressive neuropathies typically occur at anatomical sites where nerves traverse fibro-osseous tunnels or muscular and fibrous structures, whereas non-compressive neuropathies may result from trauma, infection, or inflammatory processes.[4] In healthcare settings, high-precision tasks and repetitive movements can lead to these stresses becoming chronic.

Neurodynamic tests are frequently applied to assess neural tissue mobility and mechanosensitivity. Upper Limb Neural Tension Tests (ULNTs), also referred to as neural tissue provocation tests, are established clinical tools for evaluating neural involvement by applying controlled mechanical stress. There are three main types of ULNTs, each assessing a specific nerve, with ULNT1 for the median nerve, ULNT2 for the radial nerve, and ULNT3 for the ulnar nerve. These tests apply controlled mechanical stress through specific limb positions to evaluate neural response and mobility.[5] While these tests are traditionally used in symptomatic populations to reproduce clinical pain, in asymptomatic individuals, they serve to provoke and identify subclinical neural responses, such as a stretching sensation or tingling, that indicate mechanical sensitivity. According to Wainner's criteria, a test is considered positive if it reproduces symptoms or provokes sensations, shows a discrepancy of more than 10 degrees in elbow extension or wrist flexion between both limbs, or if symptoms are modulated by structural differentiation, such as with contralateral cervical side-bending.[4,5]

Similarly, Lower Limb Tension Tests (LLTTs), including the Slump Test, Straight Leg Raise (SLR), and Prone Knee Bend test, are used to evaluate neural tissue mobility in the lower extremities, particularly involving nerve roots from L2 to S1. These tests assist in identifying early neural mechanosensitivity and nerve-related dysfunctions associated with pain, tingling, or numbness, and they play a vital role in clinical diagnosis and preventive screening.[6,7]

Beyond symptom identification, neurodynamic assessment focuses on evaluating nerve movement and length in relation to surrounding joints and soft tissues. When neural mobility restrictions are identified, interventions such as nerve gliding or mobilization are used to restore optimal neural function. Thus, the primary objectives of neurodynamic treatment include reducing neurological symptoms, improving range of motion, and normalizing neural responses to mechanical stress. Previous studies have demonstrated that neurodynamic techniques enhance neural mobility, leading to improved joint function and efficient movement patterns in both the upper and lower extremities.[8]

Although neurodynamic tests are well established in symptomatic populations, data on neural mobility and neurodynamic responses across occupational groups in asymptomatic healthcare professionals remains limited. Therefore, this study was carried out to evaluate neural tissue extensibility in both upper and lower limbs of asymptomatic healthcare professionals using standardized neurodynamic tests and to determine its association with years of work experience, aiming to identify early neural mobility limitations and to provide insight for preventive strategies.

Materials and Methods

The study was carried out at Fauji Foundation Hospital, Margalla Institute of Health Sciences, Pakistan Institute of Medical Sciences, and Holy Family Hospital, Pakistan, from 20th December 2024 to 4th August 2025. Ethical approval for the study (Project No. FF/FUCP/932-13/DPTF2008) was obtained from the Ethical Review Committee (FF/FUMC/215-512/Phy/24) and Institutional Research Committee (FF/FUCP/932-13/DPTF2008) of the Foundation University School of Health Sciences (FUSH).

A total of 384 participants was determined using the OpenEpi sample size calculator, considering a 95% confidence interval and 5% error margin, based on data obtained from registered professionals listed on the official websites of the Pakistan Medical and Dental Council and the World Physiotherapy

Association. A non-probability purposive sampling method was used to make three quotas including 128 physical therapists, 128 dentists, and 128 surgeons. The healthcare professionals having no pain in upper and lower limb in the last 3 months, of both genders, aged 25–45 years, with at least 1 year of clinical practice were included. While, the Individuals with current musculoskeletal injuries, neurological disorders, or prior surgeries affecting limb function were excluded.

Upper limb neural tissue extensibility, as an outcome measure, was evaluated using neurodynamic testing. Participants were positioned supine on an examination couch to ensure comfort and an unrestricted range of motion, with the cervical region maintained in proper alignment. To isolate upper limb movements, joint positioning was progressed sequentially, beginning with shoulder movements followed by the forearm, wrist, fingers, and elbow, in accordance with Butler's guidelines. All tests were conducted bilaterally, and participants were instructed to report any discomfort or request test termination at any time.

Upper Limb Neurodynamics

The median nerve bias test (ULNT1) was performed with the shoulder girdle depressed and the glenohumeral joint abducted to approximately 90–110°, while extending the fingers and wrist and supinating the forearm as shown in Figure 1a. The sequence was completed by externally rotating the shoulder and extending the elbow to increase neural loading. Cervical lateral flexion, particularly contralateral side-bending, was added to further increase the sensitivity of test.[8]

Subsequently, the radial nerve bias test (ULNT2) was then performed in the same supine position, starting with the shoulder girdle depressed and the arm abducted about 10°, followed by flexing the fingers and wrist and pronating the forearm as shown in Figure 1b. Medial rotation of the shoulder was then applied, and the test concluded with elbow straightening, while the opposite side of the neck was laterally flexed to increase neural sensitivity.[8]

Finally, the ulnar nerve bias test (ULNT3) was conducted starting with shoulder depression and abduction ranging from 10° to 90°, followed by extending the fingers and wrist and pronating the forearm as shown in Figure 1c. The elbow was then flexed, and the shoulder rotated laterally in sequence, with contralateral cervical lateral flexion incorporated at the end.[8]

A test was considered positive according to Wainner's criteria if at least two criteria from below were met: the participant experienced symptoms such as tingling, paresthesia, or a stretching sensation; a difference of more than 10° while extending the elbow or flexing the wrist was observed between the limbs; or symptoms were altered by cervical side-bending, where ipsilateral side-bending reduced symptoms and contralateral side-bending increased symptoms.[4]

The reliability of the upper limb neurodynamic tests has been reported using the intraclass correlation coefficient (ICC), with ULNT1 and ULNT3 demonstrating moderate to good reliability (ICC 0.6–0.8) and ULNT2 showing high reliability (ICC 0.86–0.87).[9]

Lower Limb Neurodynamics

Following the assessment of upper limb neural extensibility, lower limb neural tissue extensibility was evaluated using standardized neurodynamic tests, including the Slump Test, Passive Straight Leg Raise (SLR) test, and Prone Knee Bend test as shown in Figure 2. These tests were performed using established protocols to assess neural tension and mobility of the lumbosacral and femoral nerve roots (L2–S1).

The Slump Test was performed with participants seated, with hands placed behind the lower back to maintain a neutral spinal position as shown in Figure 2a. The test was initiated by flexion of the thoracic and lumbar spine. In the absence of symptoms, cervical flexion was added, followed by extension of one knee. If pain was reported, the neck was returned to neutral; persistence of pain or inability to fully extend the knee with added ankle dorsiflexion was considered a positive test result.[6] The Slump Test has demonstrated acceptable inter-rater reliability, with an intraclass correlation coefficient (ICC) of 0.80.[10]

The Passive SLR test was performed with participants in a supine position as shown in Figure 2b. The examiner maintained the knee in full extension while passively flexing the hip to elevate the lower limb. The test was considered positive if pain radiating along the lower extremity occurred at an angle less

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than 60°, corresponding to the distribution of the lower lumbar nerve roots, most commonly L5 or S1.[11]
The Straight Leg Raise test demonstrates excellent reliability, with reported intra- and inter-rater ICC values ranging from 0.97 to 0.99.[12]
The Prone Knee Bend test, used to assess femoral nerve tension, was performed with participants lying prone as shown in Figure 2c. The examiner stabilized the pelvis to prevent anterior rotation while passively flexing the knee to end range, ensuring contact between the heel and buttock and maintaining neutral hip rotation. The presence of unilateral neurogenic symptoms, such as pain or paresthesia in the lumbar region, buttock, or anterior thigh between 80° and 100° of knee flexion, was indicative of reduced neural extensibility.[13] This test demonstrated good intra-examiner reliability (ICC = 0.85) and excellent inter-examiner reliability (ICC = 0.92).[14]
Data collection was conducted in dedicated, quiet examination rooms across the participating hospitals to minimize external distractions. Healthcare professionals meeting the inclusion criteria were carefully enrolled, and prior to their involvement, all individuals gave their informed consent. To ensure standardization across all participants, all neurodynamic tests were performed on a high-low adjustable physiotherapy plinth by a single trained examiner (or specifically trained team) to maintain consistency in force and speed of movement. Participants were positioned according to standardized protocols, and a goniometer was used to precisely measure the 10° discrepancy in range of motion required for a positive result. Initially, demographic information was recorded for each participant, including name, age, gender, work experience, and body mass index (BMI). Following this, standardized upper and lower limb neural tension tests were performed on each limb to assess neural tissue extensibility. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize demographic data and neurodynamic test responses. To determine the correlation between work experience and neural tissue extensibility, the Spearman correlation (r_s) was applied. All analyses were performed using the IBM Statistical Package for Social Sciences (SPSS) version 23, with a p-value of <0.05 considered statistically significant.

Results

The sample consisted of 384 individuals mainly females 271 (70.6%), with the mean age of 29.33 ± 4.60 years. Most of the participants (34.1%) were within the normal weight range (18.5-22.9kg/m^2), while majority 216(56.3%) of them had 1-3 years of work experience, as shown in Table I. The analysis of neural tissue extensibility was primarily categorized by professional groups (surgeons, dentists, and physical therapists) and further evaluated based on years of work experience.
ULNT1 showed predominant median nerve involvement, with greater right-sided prevalence across all professions, especially dentists 46(35.9%). While ULNT2 demonstrated low positive response bilaterally, suggesting minimal right (10.4%) radial nerve involvement in all participants. ULNT3 also depicted positive response, reflecting ulnar nerve involvement, higher in surgeons 31(24.2%), particularly on the right side. In brief, dentists generally exhibited higher positive response for most of the neural tests of upper limb as shown in Table II. The prolonged static loading during repeated fine motor skills pose increased mechanical stress on neuronal structures leading to reduced neural flexibility over time.
Following the assessment of upper limb neural tension, lower limb neural extensibility was evaluated using the slump test to examine the lumbosacral and sciatic nerve pathways. Right 29(22.7%) and left 27(22.1%) sided slump test demonstrated positive response predominantly in surgeons followed by physical therapists and dentists. The prone knee bend test showed a relatively low response of femoral nerve tension across all participants as shown in Table III.
The surgeons exhibited relatively high prevalence for the right 20(15.6%) side and left 18(14.1%) side for prone knee bending. The occupational demands of surgeons, including prolonged standing with sustained static postures and frequent forward trunk inclination during lengthy surgical procedures may adversely affect lower limb neural extensibility. As physical therapists are routinely exposed to maintain a prolonged posture with repeated bending and frequent patient handling activities, thus in passive straight leg raise test, physical therapists

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demonstrated a higher frequency of positive responses, with 31(24.2%) and 27(21.1%) for right and left side respectively. (Table III)

A statistically significant correlation between work experience and neural tissue extensibility of upper and lower limb is demonstrated in Table IV where the p-value was <0.05 for all the tests.

Table I: Demographic Profile of Research Participants (N= 384)

Age(years), mean(SD)				
Surgeons	29.94(4.96)			
Dentists	29.58(5.22)			
Physical therapists	28.46(3.28)			
Total	29.33(4.60)			
Gender n (%)				
	Male		**Female**	
Surgeons	64(50)		64(50)	
Dentists	21(16.4)		107(83.6)	
Physical therapists	28(21.9)		100(78.1)	
Total	113(29.4)		271(70.6)	
Body Mass Index n(%)				
Underweight (18.5kg/m2)	37 (9.6)			
Normal (18.5-22.9kg/m2)	131 (34.1)			
Overweight (23-24.9kg/m2)	94 (24.5)			
Obese (>25kg/m2)	122 (31.8)			
Work Experience n(%)				
	1-3 years	**4-6 years**	**7-9 years**	**>10 years**
Surgeons	69(53.9)	38(29.7)	9(7)	12(9.4)
Dentists	68(53.1)	28(21.9)	15(11.7)	17(13.3)
Physical therapists	79(61.7)	35(27.3)	7(5.5)	7(5.5)
Total	216(56.3)	101(26.3)	31(8.1)	36(9.4)

Table II: Descriptives Of Positive and Negative Responses in Upper Limb Tension Tests of Research Participants (N= 384)

Profession	Response	ULNT1 Right	ULNT1 Left	ULNT2 Right	ULNT2 Left	ULNT3 Right	ULNT3 Left
Surgeons	Positive	42 (32.8%)	37 (28%)	15 (11.7%)	17 (13.3%)	31 (24.2%)	24 (18.8%)
	Negative	86 (67.2%)	91 (71.1%)	113 (88.3%)	111 (86.7%)	97 (75.8%)	104 (81.3%)
Dentists	Positive	46 (35.9%)	41 (32%)	18 (14.1%)	17 (13.3%)	24 (18.8%)	23 (18%)
	Negative	82 (64.1%)	87 (68%)	110 (85.9%)	111 (86.7%)	104 (81.3%)	105 (82%)
Physical therapists	Positive	44 (34.4%)	36 (28.1%)	07 (5.5%)	07 (5.5%)	22 (17.2%)	17 (13.3%)
	Negative	84 (65.6%)	92 (71.9%)	121 (94.5%)	121 (94.5%)	106 (82.8%)	111 (86.7%)

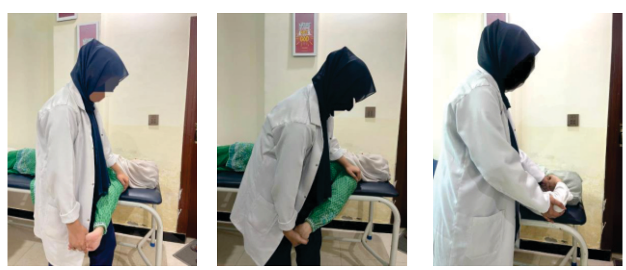
Table III: Descriptives Of Positive and Negative Responses in Lower Limb Tension Tests of Research Participants (N = 384)

Profession	Response	Slump Test		Prone Knee Bend Test		Passive Straight Leg Raise Test	
		Right	Left	Right	Left	Right	Left
Surgeons	Positive	29 (22.7%)	27 (22.1%)	20 (15.6%)	18 (14.1%)	28 (21.9%)	21 (16.4%)
	Negative	99 (77.3%)	101 (78.9%)	108 (84.4%)	110 (85.9%)	100 (78.1%)	107 (83.6%)
Dentists	Positive	22 (17.2%)	20 (15.6%)	17 (13.3%)	17 (13.3%)	29 (22.7%)	26 (20.3%)
	Negative	106 (82.8%)	108 (84.4%)	111 (86.7%)	111 (86.7%)	99 (77.3%)	102 (79.7%)
Physical therapists	Positive	25 (19.5%)	26 (20.3%)	15 (11.7%)	11 (8.6%)	31 (24.2%)	27 (21.1%)
	Negative	103 (80.5%)	102 (79.7%)	113 (88.3%)	117 (91.4%)	97 (75.8%)	101 (78.9%)

Table IV: Association Between Work Experience with Upper and Lower Limb Neural Tissue Extensibility of Research Participants (N=384)

		Upper limb neural tissue extensibility					
		Dominant ULNT1	Non-dominant ULNT1	Dominant ULNT2	Non-dominant ULNT2	Dominant ULNT3	Non-dominant ULNT3
Work Experience	r_s	0.15	0.14	0.39	0.41	0.30	0.32
	*Sig. (2-tailed)	0.002	0.006	0.000	0.000	0.000	0.000
	N	384	384	384	384	384	384
		Lower limb neural tissue extensibility					
	r_s	Right Slump Test	Left Slump Test	Right Prone Knee Bend Test	Left Prone Knee Bend Test	Right Passive Straight Leg Raise Test	Left Passive Straight Leg Raise Test
		0.31	0.30	0.42	0.43	0.25	0.34
	*Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
	N	384	384	384	384	384	384

*Correlation is significant at <0.05



a) ULNT1 b) ULNT2 c) ULNT3

Figure 1. Upper Limb Neurodynamic Testing (ULNT) Procedure

Discussion

Reduced nerve extensibility is commonly associated with occupations involving prolonged and repetitive work tasks. Among these, healthcare professionals exhibit a higher rate of musculoskeletal issues

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a) Slump Test b) Passive SLR c) Prone Knee Bend Test

Figure 2. Lower Limb Neurodynamic Testing Procedure

compared to other professions due to substantial job demands.

In current study, median nerve exhibited highest involvement 46(35.9%) particularly in dentists, followed by physical therapists 44(34.3%) and surgeons 42(32.8%). Previous literature elucidates multiple ergonomic risk factors in dental practice, including repetitive clinical procedures, sustained wrist postures and hand exertions. Prolonged contact stress from dental instruments further increases mechanical load over carpal tunnel contributing to the compression of median nerve.[15]

Pejčić N et al. found that the dentists who maintained a static working posture (sitting or standing) were two times more likely to have musculoskeletal pain. The study also explored that 32.3% of dentists reported wrist pain and numbness after performing endodontic interventions.[16]

Sabike et al. reported that 24.2% of dentists experience median nerve compression at the wrist.[17]

Julien et al. stated that surgeons, dentists and physical therapists report for wrist pain as 39.1%, 38.8% and 31.3% respectively. This may be attributed to high precision and procedural constraints of interventions, including limited access and tool-related risks while physical therapists perform manual therapies including patient handling and transfer, which place greater strain on the wrists and hands. Moreover, this study also explored that lower limbs were least affected for all health professionals, ranging from 15 to 25%.[18]

Another study reported that over 15% of surgeons were affected by carpal tunnel syndrome.[19] The findings are consistent with the previously published studies across various occupations, with wrist pain and numbness identified as the most prevalent conditions among the surveyed surgeons.

The results of the present study align with the previous study which indicated that median nerve involvement was the most prevalent (16.2%) in dentists, with greater involvement on the dominant side than the non-dominant side.[8] The present study showed involvement of median nerve as 42(32.8%) compared to the radial 18(14.1%) and ulnar nerves 24(18.8%) respectively.

For lower limb, 56(36%) and 38(24%) surgeons depicted high positive response for slump and prone knee bending test. The surgeons have long work hours, involving standing in awkward postures, challenges with various instrument design.[20] While, in current study, 58(45.3%) of physical therapists, exhibited high response in straight leg raise. Identifiable risk factors for the reduced lower limb extensibility in physiotherapists include bending or twisted postures during patient transfers or repositioning, prolonged standing postures as well as joint and soft-tissue mobilization requiring high force manual therapy.[21,22]

Furthermore, there was a statistically significant relationship ($p<0.05$) between years of experience and neurodynamics in current study. Likewise, Saad M Alqahtani et al. reported that the years of practice were associated ($p<0.001$) with work-related neuro-musculoskeletal symptoms in surgeons.[19] Goyal et al. reported no correlation ($p>0.05$) between the years of experience and the neural tissue extensibility in healthcare professionals.[8]

The findings indicate that median nerve tension is the most prevalent neural restriction among healthcare professionals, particularly in dentists, while lower limb nerves are commonly affected in long-standing position. All healthcare professionals consistently show higher neural involvement, supporting the protective role of physical activity and ergonomic practices. Early detection of subclinical neural tension through neurodynamic testing can guide preventive strategies to mitigate work-related neural disorders.

Key limitations of this study include its cross-sectional design, which restricts causal inference, and the absence of detailed ergonomic assessments. It is recommended to use longitudinal designs for future research to investigate the prolonged effects of occupational workload, including larger and more diverse samples. Incorporation of comprehensive ergonomic evaluations is essential. Additionally, the impact of preventive exercises and workplace interventions on neural tension and musculoskeletal pain should be explored.

Conclusion

Occupational demands may contribute to reduce neural extensibility in healthcare professionals, particularly right and left median nerve as 34.4% and 29.7% in upper limb, while in lower limb, 22.7% and 18.2% for right and left passive straight leg raise respectively. Moreover, dentists exhibited highest response for median nerve, surgeons for slump and prone knee bending whereas physical therapists for passive straight leg raise test. Early screening through neurodynamic testing, combined with targeted preventive strategies such as ergonomic interventions and regular exercise, may help mitigate the development of work-related neural disorders and preserve long-term neuromuscular health.

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CONFLICT OF INTEREST
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DATA SHARING STATEMENT
The data that support the findings of this study are available from the corresponding author upon request.