Normal sensory and range of motion (ROM) responses during Thoracic Slump Test (ST) in asymptomatic subjects

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The purpose of the study was to determine the normal sensory and range of motion (ROM) responses during the movement components of Thoracic Slump Test (Thoracic ST) in asymptomatic subjects. Sixty asymptomatic subjects were included in the study. Thoracic ST was performed in two sequences, proximal initiation, which was proximal to distal and distal initiation, which was distal to proximal. Subjects were randomized into four groups depending on the order of sequences and sides. Outcome measures of sensory responses (intensity, type, and location) and ROM responses were recorded after each sequence. Friedman's test was done to compare between sensory responses of the subjects. Between-component comparison for prevalence of sensory responses within each sequence was done using Kruskal-Wallis test and Wilcoxon signed ranks test was used for between-component comparisons of intensity of symptoms within each sequence of testing. Independent *t* test was used to assess the ROM responses. Results show the prevalence of sensory responses, its nature, area and intensity. These sensory and ROM responses may be considered as normal response of Thoracic ST. The intensity of the symptoms of proximal initiation sequence (1.09 ± 1.35 cm) was significant ($P < 0.05$) when compared to distal initiation sequence (0.08 ± 1.26 cm). The change in the ROM was significant ($P < 0.05$) for distal initiation (7.55 ± 4.51 degrees) when compared to proximal initiation (4.96 ± 3.76 degrees). These normal responses may be used as a reference when using the Thoracic ST as an assessment technique.

Keywords: Spine, Thoracic Sympathetic slump, Mobilization, Normal response, Neurodynamics

Introduction

The Thoracic Slump Test (ST) is a neurodynamic test (NDT) proposed to assess the mechanosensitivity of the sympathetic trunk in the thoracic region.¹ Thoracic ST was also denoted as Sympathetic ST or the Slump Long Sitting with Sympathetic Emphasis.^{2,3} The Thoracic ST was suggested as an extension of the original ST proposed by Maitland,⁴ by adding thoracic movement components in order to specifically influence the thoracic part of Sympathetic Nervous System (SNS).⁵ The basic underlying principle behind NDT using Thoracic ST was hypothesized to be the mechanical and physiological continuity of the SNS,⁶ and the ability of the SNS to adapt during movements.⁷ Thoracic ST loads various structures in the vertebral column like vertebral bodies, intervertebral discs, spinal ligaments, arteries, veins, connective tissues of the Central nervous system dorsal root ganglia, etc. and also structures outside the vertebral column such as the sympathetic trunk, sympathetic

ganglia, posterior thigh and leg muscles.⁸ Thus, all these structures can contribute to the symptoms during the Thoracic ST. According to Shacklock, classification of symptom responses elicited during neurodynamic testing include normal and abnormal responses, where abnormal responses are further subdivided into positive (neural) and negative (non-neural) responses on structural differentiation. The ability to isolate neural structures is an important issue in structural differentiation and toward making diagnosis.⁹ Sensory responses include location, intensity and quality of symptoms while motor responses include resistance pattern, range of motion (ROM) and muscle activity.¹⁰

In contrast to the ST, the neurodynamic properties of Thoracic ST were not reported previously except anecdotal evidence¹ and a few preliminary studies.^{2,3,11} The neurophysiological effects of Thoracic ST include sudomotor and vasomotor responses. Previous authors have done studies to determine the direct physiological responses of the Thoracic ST- vasomotor, sudomotor, skin temperature and skin conductance,² which indirectly established the construct validity of the

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Thoracic ST.¹² Thoracic ST was found to have direct sympathoexcitatory effects measured by sympathetic outflow significantly in upper limbs² and insignificantly in lower limbs.³ Thoracic ST has also shown significant improvement in pain and function in a patient with Complex Regional Pain Syndrome-1 (CRPS-1) in lower limbs.¹¹ The 'sympathetic slump' has been suggested as a selective examination and treatment technique for patients with features of Sympathetically Mediated Pain.¹³

The normal responses of Upper limb NDTs,¹⁴ and ST^{15,16} are available in literature. However, studies on clinical responses namely sensory and ROM responses of Thoracic ST could not be found. This study was aimed to obtain the normal sensory and ROM responses for Thoracic ST.

Methods

Study design

A cross-sectional study was conducted using random order repeated measures design. Ethical approval for this study was granted by the Time Bound Research Ethics Committee of the institution, in January 2009.

In the original description of Thoracic ST, the components can be added from proximal to distal and/or distal to proximal. In this study, we considered testing both sequences, the proximal initiation and the distal initiation. Participants were then randomly assigned to receive either of the order of test sequences by simple randomization using Research Randomizer™ software (<http://www.randomizer.org/>). Testing one sequence would bear an effect during testing the other. In a previous study, author has suggested randomization of order of testing to minimize the effect of testing one sequence on the other, as changing the order of test sequences would alter the neurodynamic responses.¹⁷ Group A consisted of participants in whom proximal initiation was performed first, followed by distal initiation and Group B consisted of subjects in whom distal initiation was performed first, followed by proximal initiation. Choice of side tested first was also randomly assigned. The subgroup RL involved right side tested first and LR involved left side first tested for Thoracic ST. Thus there were four groups: ARL (proximal initiation was performed first on right side), BRL (distal initiation was performed first on right side), ALR (proximal initiation was performed first on left side), and BLR (distal initiation was performed first on left side).

Participants

A sample of convenience of adult students, caregivers, hospital and college staff of both genders were recruited, and upon acceptance, completed written informed consent for screening and study procedure. Consented participants were then screened by the

tester for inclusion into the study if the participants were free of symptoms during ROM testing. Those subjects with history of hypertension, hyperhidrosis, obesity, history of previous spine surgery, scars or wounds over the posterior aspect of back, thigh, knees or ankle and also over the lateral aspect of trunk, symptoms in spine or extremities in past six months, neuromuscular disorders, trauma to spine or extremities, headache were excluded.

Included participants were then tested for Thoracic ST based on selection of side (right/left) and addition of test components (proximal-distal or distal-proximal).

Procedure

The Thoracic ST used in this study was as per the original description given earlier by Butler⁶ and Slater² and studied later by Cleland.^{11,18} We studied the normal responses of the Thoracic ST for sensory and ROM changes during the testing. Participant was positioned in the long sitting position; sacrum was stabilized using the sacral block, knees were strapped to the plinth using fastening belt to maintain full extension. Participant's hands were clasped behind together. Instructions were given not to hold the breath and to perform relaxed breathing during the testing.

The tester was in high kneeling position behind the subject on the plinth. Tester's one hand was on participant's contra lateral shoulder while the other hand was positioned to perform either cervical flexion (CF) or ipsilateral costovertebral mobilization (CVM).

Test components of left-side Thoracic ST

Proximal initiation

It was performed to determine effect of cervical position on ankle dorsiflexion (AD) ROM (Fig. 1). The following steps were followed: Right ankle was maintained in 20 degrees of dorsiflexion with the help of a prefabricated ankle-foot orthosis. The components performed were CF, slouching of the trunk (S), thoracic right lateral flexion (TLF), thoracic right rotation (TR), left AD. Left CVM was given at level of 10th, 11th, and 12th costovertebral joints.¹¹ Two glides were given at each level at a frequency of 0.5 Hz as suggested by Maitland.¹⁹ The sympathetic trunk lies anteriorly to the costovertebral joint at these levels. Dorsiflexion ROM was measured on left ankle with cervical spine in flexion, followed by cervical spine in extension. Similar procedure was performed on right side.

Distal initiation

It was performed to determine effect of ankle position on CF ROM. (Fig. 2). The following steps were followed: both the ankles were maintained in 20 degrees of dorsiflexion with the help of the ankle-foot

Figure 1 Starting position of the participant for Proximal initiation (left side). (A) Costovertebral mobilization; (B) Measurement of ankle dorsiflexion with cervical spine in flexion; (C) Measurement of ankle dorsiflexion with cervical spine in extension.

orthosis. The components were S, right TLF and right TR. The starting position of cervical spine was noted using the CROM. Then CF was added followed by CVM. CF ROM was measured first with both ankles in dorsiflexion and later in full plantar flexion.

Sensory responses

Sensory responses were noted for both sides of testing in each participant. The participants were asked to report any kind of sensation they felt during the procedure. The responses that were noted after addition of each component were nature, location on the body chart and intensity of perceived symptoms on a 10 cm visual analogue scale (VAS) of 0–10 where 0 was ‘no discomfort’ and 10 was ‘maximum discomfort’ elicited during test component/procedure.

ROM responses

ROM responses included measurements of AD and CF ROM done using standard universal goniometer and cervical ROM CROM device.²⁰ The CROM is reported to be a valid and reliable tool for measurement of cervical spine ROM earlier (intra-rater

reliability: ICC=0.87; criterion validity: flexion, $r=0.97$ and extension, $r=0.98$).^{21,22}

Data collection

All outcome measures were taken once by an independent blinded observer who was a post-graduate physiotherapist. The same observer measured the outcomes for single subject. The observer did not know what the recorded outcomes meant with respect to the procedure being done. During the data collection, the tester was also blinded to the values recorded. We ensured adequate blinding during instrument placement by keeping the measurement readings of the instruments opposite to the side of the assessing testers.

Data analysis

Sensory responses were collected as qualitative and quantitative data and analyzed descriptively using percentiles. Prevalence (n/N) was noted as the number of times the responses (n) were elicited in relation to total number of times (N) the test was performed. Since the test was performed twice on each participant (for both sides), the total number (N) became twice the number. This prevalence was calculated for

Figure 2 (A) Starting position of the participant for Distal Initiation (left side); (B) CROM measurement of cervical spine flexion in initial position; (C) CROM measurement of cervical spine flexion in final position; (D) CROM measurement of cervical spine flexion with ankle in plantar flexion.

reporting of sensory symptoms with addition of movement components, reporting of first onset of sensory responses for each movement component and the quality of symptoms elicited during the procedure.

Repeated measures Analysis of variance with Friedman's test was done to compare between sensory responses of the subjects. Between-component comparison for prevalence of sensory responses within each sequence was done using Kruskal-Wallis test and Wilcoxon-signed ranks test was used for between-component comparisons of intensity of symptoms within each sequence of testing. In within-group analysis, the ROM responses were compared between two structural differentiation components and between-sides of testing using paired *t*-test. Between-group analysis for ROM responses was done using independent *t*-test. All analyses were performed using statistical package for social sciences (SPSS) version 16.0 for Windows (SPSS Inc., IL, USA) with the level of significance set at 0.05.

Results

A total of 80 subjects were approached from February 2009 to January 2010, of which 75

consented and volunteered to participate in the study. Fifteen subjects were excluded (previous history of back pain, $n=11$; neck pain, $n=4$) (Fig. 3). A total of 60 subjects were included in the study (Table 1).

Primary outcomes: sensory responses

Prevalence of sensory responses and movement component that elicited first onset of sensory responses

The prevalence of sensory responses with addition of successive test components and the prevalence trend of first onset of symptoms for each test component is provided for both the sequences (Table 2).

Nature of sensory responses

We noted different nature of sensory responses for all the components of the two sequences for both the sides (Table 3). 'Stretch' sensation was most commonly seen followed by 'pulling' sensation in both the sequences.

Area of sensory responses

The prevalence of sensory responses for both the sequences is depicted in individual body regions as shown in Fig. 4.

Figure 3 Flow of the participants through the study.

Table 1 Demographic data

	Overall (combined)	ARL	BRL	ALR	BLR
Group (N')	60	15	15	15	15
Age (years)*	23.15 ± 1.59	22.73 ± 0.88	23.67 ± 2.16	23.13 ± 1.55	23.07 ± 1.53
Gender (N')	14 (46)	3 (12)	0 (15)	3 (12)	8 (7)
Male (Female)					
Number of times tested (right + left)	120	30	30	30	30
N					

Note: All values are in N' – number of participants.

*mean ± SD.

ARL, proximal initiation was performed first on right side; BRL, distal initiation was performed first on right side; ALR, proximal initiation was performed first on left side; BLR, distal initiation was performed first on left side.

Table 2 Prevalence for sensory responses

<i>n'</i> (<i>n/N</i> %)	Test components	CF	S	TLF	TR	AD	CVM	CE	AP
Prevalence of sensory responses	Proximal initiation*	30 (25%)	49 (40.8%)	41 (39.2%)	63 (52.5%)	91 (75.8%)	86 (71.7%)	47 (39.2%)	NA
	Distal initiation*	75 (62.5%)	16 (13.3%)	20 (16.7%)	33 (27.5%)	NA	62 (51.7%)	NA	35 (29.2%)
Prevalence for 1 st onset of sensory response	Proximal initiation *	29 (24.2%)	18 (15%)	10 (8.3%)	13 (10.8%)	21 (17.5%)	0	0	NA
	Distal initiation*	32 (26.7%)	14 (11.7%)	10 (8.3%)	12 (10%)	NA	7 (5.8%)	NA	0

Note: *P value significant for changes across test components at 0.05 level.

CF, cervical flexion; S, slouching; TLF, thoracic lateral flexion; TR, thoracic rotation; AD, ankle dorsiflexion; CVM, costovertebral mobilization; CE, cervical extension; AP, ankle plantar flexion.

n, number of times participants reported sensory responses.

N, number of times tested (*N*=120).

n', prevalence of sensory responses (%).

NA, not applicable.

Table 3 Prevalence of nature of sensory responses for both sequences of testing

Nature of sensory responses <i>n'</i> (<i>n/N</i> %)	Test components	CF	S	TLF	TR	AD	CVM	CE	AP
Stretch	Proximal initiation	24 (20%)	38 (31.7%)	30 (25%)	48 (40%)	62 (51.7%)	58 (48.3%)	28 (23.3%)	NA
	Distal initiation	29 (24.2%)	13 (10.8%)	16 (13.3%)	24 (20%)	NA	48 (40%)	NA	26 (21.7%)
Pulling	Proximal initiation	5 (4.2%)	10 (8.3%)	8 (6.7%)	11 (9.2%)	25 (20.8%)	23 (19.2%)	11 (9.2%)	NA
	Distal initiation	9 (7.5%)	3 (2.5%)	9 (7.5%)	3 (2.5%)	NA	10 (8.3%)	NA	7 (5.8%)
Tingling	Proximal initiation	1 (0.8%)	1 (0.8%)	3 (2.5%)	4 (3.3%)	5 (4.2%)	4 (3.3%)	4 (3.3%)	NA
	Distal initiation	1 (0.8%)	1 (0.8%)	1 (0.8%)	0	NA	4 (3.3%)	NA	1 (0.8%)
Pain	Proximal initiation	0	1 (0.8%)	1 (0.8%)	1 (0.8%)	2 (1.7%)	1 (0.8%)	0	NA
	Distal initiation	0	0	0	0	NA	0	NA	NA
Numbness	Proximal initiation	0	0	0	0	0	0	0	NA
	Distal initiation	0	0	0	0	NA	0	NA	NA
Shooting	Proximal initiation	1 (0.8%)	1 (0.8%)	1 (0.8%)	1 (0.8%)	0	0	0	NA
	Distal initiation	0	0	0	0	NA	0	NA	NA
Pricking	Proximal initiation	1 (0.8%)	2 (1.7%)	1 (0.8%)	1 (0.8%)	0	0	0	NA
	Distal initiation	0	0	0	0	NA	2 (1.7%)	NA	1 (0.8%)

CF, cervical flexion; S, slouching; TLF, thoracic lateral flexion; TR, thoracic rotation; AD, ankle dorsiflexion; CVM, costovertebral mobilization; CE, cervical extension; AP, ankle plantar flexion.

n, number of times participants reported sensory responses.

N, number of times tested (*N*=120).

n', prevalence of sensory responses (%).

NA, not applicable.

Figure 4 Area of sensory responses for the individual components of (A) Proximal initiation (CF, cervical flexion; S, slouching; TLF, thoracic lateral flexion; TR, thoracic rotation; AD, ankle dorsiflexion; CVM, costovertebral mobilization; CE, cervical extension) and (B) Distal initiation (S, slouching; TLF, thoracic lateral flexion; TR, thoracic rotation; CF, cervical flexion; CVM, costovertebral mobilization; AP, ankle plantar flexion).

Intensity

The overall intensity of perceived symptoms on VAS (0–10 cm) during proximal initiation was 1.09 ± 1.35 (right side = 1.10 ± 1.40 and left side = 1.08 ± 1.30 , between-side difference not significant at $p=.90$), and distal initiation was 0.80 ± 1.26 (right side = 0.74 ± 1.18

and left side = 0.82 ± 1.34 , between-side difference not significant at $P=0.73$). Between-sequence comparison was not significant for overall intensity ($P=0.20$). Proximal initiation showed statistically significant difference ($Z=9.6$, $P=0.0001$) compared to distal initiation on the intensity for all the components. Proximal initiation had significantly higher intensity of symptoms for the three components: TLF ($P=0.017$), TR ($P=0.0004$) and CVM ($P=0.04$) compared to distal initiation (Table 4).

The intensity of the sensory responses observed for proximal initiation before and after was 14.48 ± 3.74 and 2.05 ± 3.15 ($P=0.0001$) respectively and for distal initiation, was 2.89 ± 3.34 and 1.41 ± 2.63 ($P=0.0001$) respectively.

ROM responses

The change in intensity for was statistically significant. During proximal initiation, the ROM of AD with CF (9.75 ± 5.75 degrees) was significantly lesser ($P=0.04$) than in cervical extension (11.87 ± 6.32 degrees). During distal initiation the ROM of CF with AD (62.75 ± 10.45) was significantly lesser ($P=0.05$) than in ankle planter flexion (70.26 ± 11.46 degrees).

The ROM difference was significantly greater ($P=0.001$) for distal initiation (7.55 ± 4.51) when compared to proximal initiation (4.96 ± 3.76) but the between-side comparison was not significant. No statistically significant difference was noted in ROM differences when compared between-orders A (2.08 ± 3.5 degrees) and B (2.62 ± 3.97 degrees).

Discussion

To our limited knowledge this is the first study on Thoracic ST that reported normal responses observed during testing. Similar study on sensory responses for original ST was earlier done by Walsh *et al.*¹⁵

We chose to study Thoracic ST which was specific to thoracic sympathetic trunk with the addition of TLF and TR.¹ This enabled us to study the responses of the Thoracic ST as an extension of the original slump test since the cervical spine components were similar between the two tests, except for the thoracic spine movements being added in the Thoracic ST.

We chose two sequences for the Thoracic ST and aimed to compare the responses between proximal initiation and distal initiation for sensory and ROM responses since NDT responses were shown to be altered with the direction of addition of movement components specific to the particular sequence. We also chose to perform sequences on right and left sides as previous study done by Wong had shown that the left sympathetic trunk predominated over the right sympathetic trunk.²³ Those findings were on symptomatic subjects. Our study did not show significant difference in between-side comparisons, the reason for which could be attributed to the

hypothetical similarity between sides in normal subjects. Between-side ROM changes during ST were also shown not to be different.²⁴ It was noticed that greater intensity of symptoms was felt during the proximal initiation sequence. This change in intensity was specific to the three movement components of the Thoracic ST which was also reiterated in previous clinical studies.^{2,3,11} TLF, TR, and CVM are the three movement components that differentiate Thoracic ST from the original ST and are specific to the sympathetic trunk. Greater strain in the nerves occurs at the site that is moved first in the sequence.¹⁰ Clinically and experimentally, it appears that the neural tissue in the component that is added first will be most challenged by the test.¹ CF was the first component of proximal initiation and it elicited the first symptom. The first component of distal initiation however did not elicit the first symptom rather it was CF, which was the last added component in this sequence. It was interesting to note that both the sequences of test had CF component that elicited symptoms first. This may be possibly attributed to relatively lesser contribution of distal components in the Thoracic ST testing. Overall, we found that successive addition of movement components in both the sequences resulted in increased number of subjects who reported symptoms elicitation during the Thoracic ST. The NDT components and sensitizing maneuvers progressively load the neural tissues which can be detected by increased symptoms with successive addition of movement components.^{10,25}

With the addition of CVM, there was a significant decrease in intensity for both the sequences. The change was significant for proximal initiation sequence which suggests that the mechanical loading of Sympathetic trunk would have been more for this sequence. This decrease in intensity also suggests that the sympathetic trunk was probably getting desensitized with CVM.

We noted decrease in intensity with structural differentiation for both sequences which confirmed that sensory responses were neurogenic. Previous studies⁶ have shown that the autonomic system is continuous with the central and peripheral nervous system, so the principle of 'nervous system as a continuum' also applies to the sympathetic trunk which was confirmed in this study. Overall, proximal initiation showed more changes in the frequency and

intensity of sensory responses. The results suggested that the mechanical loading of proximal initiation was significantly higher than in distal initiation. Therefore we suggest its use in clinical setting; distal initiation however can be used in severely or moderately irritable conditions and also for remote sequencing.

For the nature of sensory responses, 'stretch' was reported by maximum number of subjects followed by 'pulling' sensation during each component for both sequences. 'Stretch' sensation is usually present during neurodynamic testing performed on asymptomatic subjects and is thus classified into either normal or subclinical response.¹⁰

One of the drawbacks of this study was that the responses measured were mainly clinical and not physiological. Altered neural response to mechanical forces may manifest as abnormal physiological responses leading to pain and related symptoms, the condition termed as 'neural tissue mechanosensitivity' (NTM).¹⁰ NTM clinically presents with deep and aching type of pain, which is often assessed by the responses to neurodynamic testing.⁶ Previous reviews have shown the evidence of increased NTM in many patients with neuromusculoskeletal conditions²⁶ and efficacy of NDM on a variety of disorders.²⁷ We aimed to implicate sound interpretation of the Thoracic ST into clinical practice towards assessment and management of patients with disorders who present with autonomic dysfunction. The other factor not under our control was the muscle activity during the neurodynamic testing.^{10,25} In this study, pressure sensors or a pressure cuff was not used to measure any pressure exerted by the subject over the sacral block. Few other subject-related factors, like the psycho-behavioral aspects could not be controlled and might have affected the responses.

The responses obtained in the current study can be used as baseline information for evaluation of neural tissue in patients with SNS dysfunctions.

There were greater increases in ROM noted during distal initiation compared to proximal initiation but not clinically important at eight degrees as measured by CROM while proximal initiation change score was also not clinically important at two degrees.^{28,29} This might be due to greater available ROM for CF compared to AD.³⁰ The changes in ROM were comparable to ROM changes recommended as

Table 4 Between sequences comparison of intensity during thoracic lateral flexion, thoracic rotation and costovertebral mobilization components

Component	Proximal initiation (VAS/10) (cm)	Distal initiation (VAS/10) (cm)	Z value	P value
Thoracic lateral flexion	1.26 ± 1.05	0.70 ± 0.98	2.414	0.017*
Thoracic rotation	2.29 ± 1.42	1.23 ± 1.25	3.586	0.0004*
Costovertebral mobilization	3.36 ± 1.62	2.67 ± 1.71	1.985	0.04*

Note: *P value significant for <0.05.

normal response described for other NDTs.²⁴ The ROM responses were neither influenced by order of testing nor by the side tested. As such, there is no study available on the interpretation of NDTs based upon structural differentiation as an essential criterion.¹⁴ However, our findings could provide clinicians with baseline values for ROM changes that occurred for both sequences. This ROM change warrants further validation by studying ROM responses in comparison to patient populations.

In patients who present with symptoms of autonomic dysfunction from pathomechanical causes where sympathetic neural tissue mobility is impaired,³ a positive Thoracic ST will be indicated by reproduction of patient's symptoms during structural differentiation. These patients may be best treated using Thoracic ST as a treatment technique. Previous study has proposed use of TS mobilization as effective management in CRPS-1.¹¹ However, before using this test for assessment as well as a treatment technique, it is necessary to establish the normal test response of this test.

Conclusion

This study provides with the normal sensory and ROM responses of Thoracic ST. The prevalence of sensory responses increased with addition of components one after the other but decreased with CVM. The commonest sensory responses perceived by the subjects were 'stretch' and 'pull'. The commonest area of sensory response was in thigh and calf regions for proximal initiation but for distal initiation, the commonest area was in the back region. Proximal initiation showed significantly higher intensity of symptoms as compared to distal initiation for the three components specific to sympathetic trunk. Changing the order of sequences or sides had no effect on the intensity of sensory response. The ROM responses were greater for distal initiation sequence as compared to proximal initiation sequence.

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