3-Dimensional Cervical Movement Characteristics and the Influence of Thoracic Treatment on a Subgroup of Acute Neck Pain Patients

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Abstract

Objective: The purpose of this study was to investigate the influence of thoracic high-velocity low-amplitude thrust (HVLAT) manipulation on quantitative and qualitative 3-dimensional cervical spine kinematic patterns in a subgroup of patients with acute neck pain.

Methods: Thirty patients with acute neck pain, aged 20 to 59, received a thoracic HVLAT manipulation. Three-dimensional kinematics of the cervical spine were registered pretreatment and posttreatment using an electromagnetic tracking system. Quantitative and qualitative parameters were calculated for axial rotation, lateral bending, and flexion-extension movement. Subjective pain ratings were measured with the visual analogue scale and the Neck Disability Index and were collected pretreatment and posttreatment.

Results: After treatment, the range of motion of the main motion improved significantly for axial rotation ($P = .034$), lateral bending ($P < .001$), and flexion-extension ($P = .031$). Although for axial rotation as the main motion, the smoothness of the flexion-extension movement improved significantly after treatment ($P = .036$), the reverse was true for flexion-extension as the main motion. Visual analogue scale scores exhibited a statistically ($P < .001$) and clinically significant reduction of pain sensation. The mean change in Neck Disability Index scores only exhibited a statistically significant improvement 1 week after treatment.

Conclusion: Thoracic HVLAT manipulation led to positive changes in quantitative and qualitative aspects of 3-dimensional cervical spine kinematics. Because of the 1-intervention group design, external factors influencing the healing process could not be eliminated. (J Manipulative Physiol Ther 2018;41:304-314)

Key Indexing Terms: *Manipulation, Spinal; Range of Motion, Articular; Movement; Physiology; Neck Pain*

Introduction

Neck pain is generally described as pain perceived in the posterior region of the cervical spine. This region is bounded superiorly between the nuchal line, laterally by the margins of the neck, and inferiorly by an imaginary transverse line through the T1 spinous process.[1,2] Nonspecific neck pain can be defined as simple neck pain without a specific underlying disease causing the pain. Commonly used synonyms such as *tension neck syndrome* and *cervical brachial syndrome* primarily describe symptoms of nonspecific neck pain but do not offer any inferences on their possible causes. Nonspecific neck pain can be diagnosed through clinical assessment ruling out suggestions for serious conditions (red flags), for example, space-occupying lesions, vascular insufficiency, compression of the spinal cord, and traumatic or systemic inflammatory processes. The Task Force on Neck Pain and Its Associated Disorders has developed a clinical classification system for neck pain patients.[3] On the basis of specific symptoms and clinical indications, the following differentiation has been proposed: grade I = no signs of major pathology and no or little interference with daily activities; grade II = no signs of major pathology, but interference with daily activities; grade III = neck pain with neurological signs or symptoms; and grade IV = neck pain with signs of major pathology.[4]

Based on their clinical appearances, 3 different forms of neck pain are classified: acute, subacute, and chronic neck pain. Within current international research, however, different perspectives coexist regarding symptom duration of those different forms of neck pain. Whereas German literature declares neck pain with symptoms

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lasting between 0 and 3 weeks as acute, the Belgian Healthcare Knowledge Center follows the classification of Binder[5-7]: acute neck pain (<4 weeks' duration); sub-acute (1-4 months' duration); and chronic (>4 months' duration).

Symptoms of nonspecific neck pain share characteristics of symptoms of whiplash-associated disorders, grades I and II. Haldeman et al describe the following symptoms corresponding to grade I: pain, stiffness, and tenderness of the neck, but no physical signs[3]; for symptoms corresponding to grade II, the same neck complaints and other musculoskeletal impairments (eg, decreased range of motion [ROM] and tender spots). Following the Intego Network, between 1994 and 2006, the incidence rate of patients experiencing neck pain in need of medical advice accounted for 24.84% of the Belgian population.[8] However, it must be mentioned that the actual incidence rate might be even higher because of selection bias for participants who were actively seeking medical advice.

Prevalence rates of nonspecific neck pain tend to vary in Western Europe for the years 1991 to 2004. More specifically, studies have been reporting rates between 5% and 22%.[5,9-12] Following a meta-analysis of the Neck Pain Task Force conducted for the years 1980 to 2006, the 12-month prevalence rate for neck pain was 12.1% to 71.5 % in the general population and 27.1% to 47.8% in the working population.[4] Compared with numerous studies on neck pain conducted in North America, The Netherlands, and Scandinavia, research on the epidemiology of neck pain is still lacking in the German and Belgian/Flemish populations.[13,14]

Treatment of neck pain constitutes an essential cost factor within the health care system.[15] Already in 1996, Borghouts et al estimated the yearly treatment costs of patients with neck pain in The Netherlands at $686 million.[11] In Germany, costs for treatment of spine diseases are estimated at €7.2 billion, accounting for 3.2% of the gross €223.6 billion in health care costs in 2002.[5]

Physiotherapy has been proposed as an intervention for patients with neck pain; however, there is no consensus on which technique might serve as the gold standard for treatment.[16,17] Recent guidelines for physical therapists recommend different interventions, for example, stretching exercises, coordination and strengthening exercises, upper quarter and nerve mobilization, traction, cognitive/behavioral therapy, and cervical and thoracic mobilization/manipulation.[18] Manual therapeutic treatment of neck pain entails manipulation and mobilization of both the cervical spine and the thoracic spine. Both treatments are commonly combined with exercises and have been found to be efficient.[19] Martinez-Segura et al that cervical and thoracic high-velocity low-amplitude thrust (HVLAT) manipulations are similarly effective in reducing pain and improving movement functions in patients with neck pain[20] (see also Suvarnnato et al[21]). Because manual therapeutic treatment of the cervical spine might entail possible adverse effects, treatment of the thoracic spine has been recommended in the last few years.[22-24] Current literature suggests that manual therapy at the level of the thoracic spine may also have beneficial effects on nonspecific neck pain and may entail less potential risk than cervical manual therapy. Likewise, the Orthopedic Section of the American Physical Association recommends thoracic spine manipulation as treatment for acute neck pain.[25] Recent research has accumulated evidence for the effectiveness of thoracic manipulation in reducing acute neck pain, improving neck function, and increasing quality of life.[26] Studies conducted by Fernández de-las-Peñas et al revealed that even a single thoracic spine manipulation might suffice to reduce neck pain, with visual analogue scale (VAS) scores measuring subjective pain decreasing from 5.5 before the manipulation to 2.9 directly after treatment.[27] Moreover, the authors observed an increase in the cervical ROM. Other studies support the effectiveness of thoracic manipulation as a suitable treatment for mechanical neck pain.[28,29] Specifically, manipulations of the thoracic spine have led to short-term improvements in ROM and improvement of disability. Those improvements of both subjective pain ratings and muscular function can also be observed in daily practice.

Different explanations are presented for the effectiveness of thoracic manipulation as a treatment for acute neck pain. From a biomechanical perspective, normal functioning of the cervical spine highly depends on functioning of the thoracic spine. Therefore, malfunction of the thoracic spine might likely impede both muscular function and regular movements.[30] Other explanations point toward neurophysiological effects.[20,31] One model developed by Bialosky et al links mechanical stimuli (ie, manual therapeutic interventions) to neurophysiological effects such as hypoalgesia, neuromuscular and endocrine reactions, and peripheral, spinal, and supraspinal mechanisms.[32] Chu et al found that a HVLAT manipulation of the thoracic and cervical spine released an excitatory response of the sympathetic nervous system (SNS), which, in turn, was associated with pain reduction and reduced mechanosensitivity in symptomatic individuals.[33] The ROM is an often-used indicator of effects of manual therapy in patients with neck pain. Motion palpation techniques, however, have been found to be unreliable.[34,35]

In clinical practice, simple and effective 2-dimensional methods, such as use of a handheld goniometer or cervical ROM goniometer, are most often used for measurement of ROM. Although their results indicate high reliability and precision, both methods are limited by their inability to record complex movements with greater than 1 center of rotation. That is why those methods are not able to display the natural 3-dimensional movement of the cervical spine.[36] Other investigations have reported the noninvasive, suitable, and accurate application of electromagnetic tracking systems (ETSs) for biomechanical and kinesiological research on movements.[37-42]

Previous ETS studies have assessed both asymptomatic and symptomatic patients with chronic nonspecific neck pain, insidious neck pain, and whiplash-associated disorders. In the study described here, however, the focus was on patients with acute nonspecific neck pain. Electromagnetic tracking devices (Liberty, Polhemus, Colchester, Vermont) were used to register 3-dimensional positions and orientations during global cervical movement.

The aim of the study was to investigate the influence of thoracic HVLAT manipulation on quantitative and qualitative 3-dimensional cervical spine kinematic patterns in a subgroup of patients with acute neck pain. One goal of the study was to objectively and quantitatively evaluate cervical 3-dimensional kinematics before and after the intervention. Kinematic results were then compared with patients' subjective pain ratings as well as with actual functional levels.

Methods

Participants

Thirty participants of diverse ages and sex took part in the study. To obtain statistical power at the recommended 0.80 level, power analyses were performed resulting in a required n of 25 participants. All participants (17 females) were required to be at least 18 years old. Participants were aged 20 to 59 years (mean = 35.37, standard deviation [SD] = 12.54). Participants were required to have experienced acute neck pain for less than 4 weeks, with symptoms strictly isolated to the neck. Prior to baseline measurement, a history including questions regarding the onset, episode, nature, and location of pain was obtained. To confirm the absence of nerve root pain (radicular pain, radiculopathy), Spurling's test, traction/neck distraction, the shoulder abduction test, Valsalva's maneuver, and the neurodynamic upper limb tension test were performed as a physical examination.[43,44] If 1 of these tests was positive for radiculopathy, the patient was excluded from this study.

As contraindications to manipulation and thus exclusion criteria, the presence of the following "red flags" was determined: tumors, infections, bone destruction, congenital abnormalities, fracture or dislocation, compression of the spinal cord, nerve root compression with increasing neurological deficit, myelopathy, bone and joint inflammation, spinal osteoporosis, vertebral basilar insufficiency.[6]

All participants provided informed consent prior to participation in the study. The protocol of this study was approved by the Medical Ethics Committee of University Hospital Brussels and Free University Brussels (No. 143201627692).

Measurement Technique

The Polhemus Liberty is a 6-degree-of-freedom measuring device, consisting of a transmitter and 1 or more sensors. This ETS is capable of measuring and objectifying 3-dimensional coupled movements of the spine.[45,46] The transmitter generates an electromagnetic field in which the orientation of the receiver frame is defined by the receiver's x, y, and z axes with respect to the transmitter frame's x, y, and z axes. The angle alignment between these axes can be expressed mathematically with Euler's Cardan angles or with the concept of a finite helical axis. Within the electromagnetic field, each receiver transmits respective positions (x, y, and z) and orientations (azimuth, elevation, and roll) simultaneously (240 updates per second per sensor) with a statistical position sensitivity of 0.762 mm and a static orientation sensitivity of 0.15° (Liberty User Manual, Revision F, Polhemus, 2008).

Procedure

Prior to baseline measurements, all participants underwent a screening procedure followed by a history taking and the physical examination. This information was used to assess whether patients were eligible for participation in the present study. As baseline measurement, mobility of the cervical spine was assessed via electromagnetic tracking devices. In addition to 3-dimensional kinematic data, subjective pain ratings and functional level were assessed. All patients received a manual therapeutic intervention directed to the thoracic spine. Directly after the intervention, the mobility of the cervical spine and subjective pain ratings were again assessed. Functional levels were assessed a second time 1 week after the intervention.

Measurements

Mobility of the Cervical Spine. Three-dimensional kinematic movements of the cervical spine were registered using the Polhemus Liberty to track the positions of 2 sensors: 1 sensor located in a cap aligned to the middle of the os frontale, and the second sensor attached to the sternum below the incisura jugularis. Both sensors were oriented in the frontal plane. To prevent measurement irregularities from preintervention to postintervention measurements, the location of the second sensor was marked with a pencil. All ferromagnetic material was banned from the testing area to avoid interference with the measurement. During measurement, all patients were seated on a fixed wooden chair with the thoracic spine maintaining contact with the backrest. The transmitter was located at a distance of 50 cm vertically to the sternum. For calculation of the received data, a specific MATLAB routine was used (The MathWorks, Natick, Massachusetts) resulting in qualitative and quantitative data on the cervical main motions. Additionally, the motion cycle was displayed graphically (sinusoidal), representing 3 rotations along the transversal, sagittal, and longitudinal axes.

Prior to each measurement, a third receiver, which was fixed on a palpation stylus to set a 6-point reference frame, was used. The following 6 anatomic bony landmarks were used: the most lateral point of the right and left acromion; the deepest point of the incisura jugularis; the most caudal aspect of the right and left processus mastoideus; and the most dorsal aspect of the protuberantia occipitalis externa.

The reference coordination frames of head and thorax were derived from the International Society of Biomechanics. Specifically, x axes pointed to the right, y axes pointed upward vertical, and z axes were the cross-product of x and y axes. For "ratio" calculation, the direction of the y axis was inverted so that y was positive for right rotation and x was positive for lateral bending.[47] All participants received oral standardized movement instructions consisting of 3 repetitive movement cycles as an exercise. The order was fixed: left-right rotation, left-right lateral bending, and flexion-extension. Participants were instructed to carry out those movements only within a comfortable/pain-free range. All measurements were performed by the same tester.

Subjective Pain. Subjective pain experience was assessed by means of a VAS. All patients were asked to indicate their pain levels before and after the intervention. The VAS is a 100-mm line with anchors of "no pain" (0 mm) and "worst pain" (100 mm). The patients were asked to mark a location on the VAS corresponding to their respective pain level. The VAS has been found to be a highly reliable instrument for detecting immediate changes in perceived pain (intraclass correlation coefficient = 0.97).[48,49] The minimal clinically important difference (MCID) has been documented to be about 12 mm on the VAS.[50]

Functional Level. The Neck Disability Index (NDI) is the most widely used, condition-specific disability scale for patients with neck pain. This index consists of 10 items and addresses different aspects of function (eg, pain intensity, personal care, lifting, reading, and sleeping). Each item contains 6 answer choices ranging from 0 (no disability) to 5 (complete disability). The total score is reported on a 0-50 scale or as percentage score (0-100%). Patients were asked to complete the NDI before treatment (baseline measurement) and 1 week after the intervention (posttreatment measurement). Cleland et al reported a difference of 10.2 as the minimal detectable change.[51] Pool et al have documented the MCID as 10.5.[52]

Intervention

All patients were eligible to participate in this study and received a HVLAT thoracic manipulation (see below). The identification of treatment segments and the manipulation were performed by 2 orthopedic manual therapy-trained physical therapists (SOMT, Amersfoort, Netherlands). The segmental mobility of the entire thoracic spine was tested with motion palpation and prone springing palpation for pain provocation. During the HVLAT manipulation, patients lay supine with the arms crossed over the chest and the hands placed over the opposite shoulder. The arm was pulled downward to create spinal flexion down to the upper thoracic spine. The therapist used his hand ("pistol grip") to stabilize the inferior vertebra of the restricted motion segment. The body was pushed down to perform a HVLAT gap manipulation. The same investigator performed all HVLAT manipulations.

Data Analysis

Data were stored in Microsoft Excel spreadsheets, and pre-processing of kinematic data was performed in MathCAD 15 mathematical software. In MathCAD, a full ROM cycle of the main motion was selected (Figs 1 and 2). The results were analyzed using SPSS Version 22 (IBM, Armonk, New York). The following quantitative kinematic parameters were calculated: ROM of the main and conjunct motion components (positive values of the parameters indicate extension, axial rotation to the left, and lateral bending to the left, and negative values indicate flexion, right axial rotation, and right lateral bending); the cross-correlation between the main and coupled motions (with positive values indicating ipsilateral coupling); and the ratio of the main motion to the coupled motion (with values >1 indicating more rotation compared with lateral bending). The following qualitative kinematic patterns were calculated: root-mean-square value of the jerk for each motion component (jerk index), standard error of measurement on the deviation of the original data from a sixth polynomial fitting of the curve (measure of smoothness of the movement).[42,53]

The Kolmogorov-Smirnov test was used to determine whether there was a normal distribution of the outcome data (all P values > .050). Paired sample t tests were performed to investigate differences in kinematic movement patterns, subjective pain ratings, and functional levels from pre-intervention to postintervention.

Results

Descriptives

Table 1 summarizes the baseline characteristics of the participants. All 30 patients rated pain intensity on the VAS as moderate (mean = 4.05, SD = 1.71), and the functional disability as mild (mean = 10.37, SD = 4.47).

Mobility of the Cervical Spine

Because of technical issues, kinematic data from some participants could not be registered and were therefore excluded from the analysis. The complete data sets for preintervention and postintervention measurements

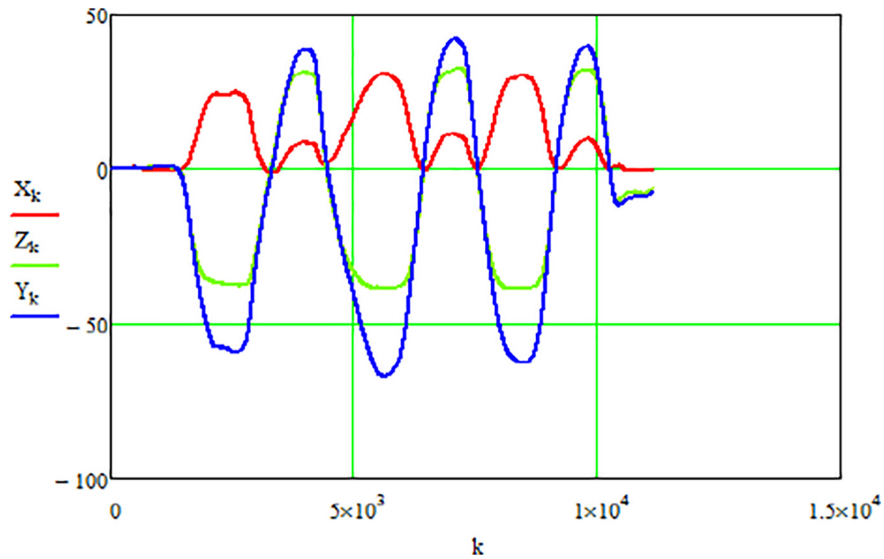

Fig 1. *Pretreatment: Graphical representation of 3-dimensional movement characteristics during active axial rotation of participant 25.* X_k *= flexion-extension,* Y_k *= axial rotation,* Z_k *= lateral bending.*

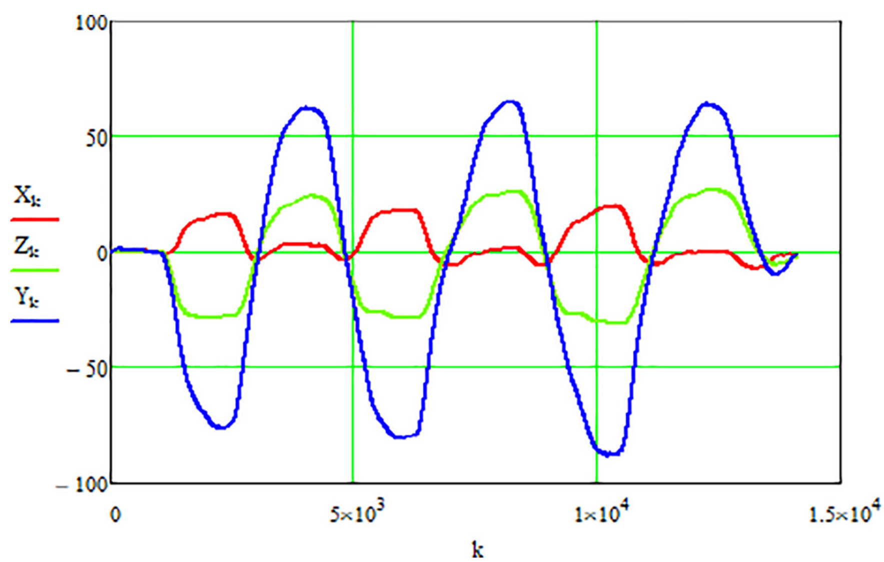

Fig 2. *Posttreatment: Graphical representation of 3-dimensional movement characteristic during active axial rotation of participant 25.* X_k *= flexion-extension,* Y_k *= axial rotation,* Z_k *= lateral bending.*

included 21 participants for axial rotation, 28 participants for lateral bending, and 16 participants for flexion-extension.

Axial Rotation

The HVLAT manipulation significantly increased the quantitative kinematic parameters for ROM for axial rotation (main motion), $P = .034$, 95% confidence interval (CI) = 1.49 to 17.20, and coupled lateral bending approached significant improvement, $P = .054$, 95% CI = 0.72 to 8.3. Specifically, the mean range for axial rotation as main motion improved from 130.78° before the manipulation to 140.48° directly after the manipulation. Similarly, the mean range of the coupled lateral bending component increased from 82.69° before the manipulation to 92.14° after the manipulation.

Even for the qualitative parameter variability of flexion-extension—as a measure of the smoothness of the flexion-extension movement—there was a significant difference,

Table 1. *Baseline Subjective Pain Ratings and Functional Level*

	n	Mean	SD
Number of patients (*n*)	30		
Sex (male/female)	13/17		
Age		35.36	12.54
Visual analogue scale		4.05	1.71
Neck Disability Index		10.37	4.47

SD, standard deviation.

Table 2. *Cervical Kinematics During Axial Rotation: Comparison of Before and After Thoracic High-Velocity Low-Amplitude Treatment*

	Pretreatment		Posttreatment		
Kinematics	Mean	SD	Mean	SD	*P*
Quantitative Parameters					
Cross-correlation	–0.37	0.37	–0.30	0.36	.400
Ratio	1.60	0.83	1.41	0.49	.401
Range flexion-extension	37.92	11.94	43.00	10.18	.147
Range axial rotation	130.78	22.08	140.48	17.86	.034 [a]
Range lateral bending	82.69	24.24	92.14	23.64	.054
Qualitative Parameters					
Variability of flexion-extension	2.08	1.14	2.46	1.13	.036 [a]
Variability of axial rotation	1.94	0.93	2.12	1.23	.527
Variability of lateral bending	1.51	0.66	1.61	0.68	.347
Jerk on flexion-extension	0.01	0.01	0.01	0.01	.605
Jerk on axial rotation	0.01	0.01	0.00	0.01	.056
Jerk on lateral bending	0.01	0.01	0.01	0.01	.999

df, degrees of freedom; *SD*, standard deviation.
Means and SDs are expressed in degrees. Jerk is an absolute value (smaller values indicate a smoother movement).
[a] Level of significance with $P < .05$, paired *t* test, $df = 20$.

$P = .036$, 95% CI = 0.72 to 0.83, which indicates a higher smoothness of movement after the manipulation (mean = 2.46, SD = 1.13) compared to baseline (mean = 2.08, SD = 1.14). The cross-correlation (CC) indicates the relationship between the main axial rotation and the coupled lateral bending. At the baseline measurement, the mean CC was 0.37, and after treatment it was –0.30. This negative CC indicates contralateral coupling pattern. The mean of the ratio is constantly greater than 1, which indicates that the axial rotation component was greater than the lateral bending component.

The smoothness of the movement is also expressed by the deviation from the polynomial function of this coupled axial rotation motion component and the jerk index. This index exhibited a trend toward improvement, $P = .056$, 95% CI = 0.00 to 0.01, after the manipulation (mean = 0.00, SD = 0.01) compared with baseline (mean = 0.01, SD = 0.01) (Table 2).

Lateral Bending

The HVLAT manipulation significantly increased the quantitative kinematic parameters for ROM for lateral bending as main motion, $P = .000$, 95% CI = 6.67 to 12.86. The mean range for lateral bending improved from 68.80° before the manipulation to 80.55° directly after the treatment. This indicates a greater movement from the main motion component directly after the manipulation compared with the baseline measurement. The mean ROM of flexion-extension also exhibited only an approach toward significant improvement, $P = .070$, 95% CI = 0.53 to 4.12.

At baseline, the mean CC was 0.47 (SD = 0.41), and after treatment, it was 0.63 (SD = 0.46). This indicated ipsilateral coupling patterns for lateral bending as the main motion component and axial rotation as the coupled motion component. The mean of the ratio is constantly lower than 1, which indicates that the lateral bending component is greater than the axial rotation component. The jerkiness of the motion showed no difference between premeasurements and postmeasurements (Table 3).

Flexion-Extension

The mean range of the main flexion-extension motion component changed from 110.11° (SD = 20.77) at baseline to 118.81° (SD = 18.64) after treatment. This difference was significant, $P = .031$, 95% CI = 2.61 to 20.29. Even for the qualitative parameters, that is, jerk of the flexion-extension movement and jerk of axial rotation, there was a significant difference, $P = .013$, 95% CI = 0.02 to 0.08, and $P = .016$, 95% CI = 0.001 to 0.006. This indicates a lower smoothness of movement after the manipulation (mean = 0.30, SD = 0.72; mean = 0.13, SD = 0.22) compared with baseline (mean = 0.13, SD = 0.06; mean = 0.07, SD = 0.01) (Table 4).

Subjective Pain and Functional Level

Visual analogue scale scores decreased from 4.05 cm (SD = 1.71) at baseline to 1.71 cm (SD = 1.29) after the manipulation. This change was statistically significant ($P < .001$, 95% CI = 0.61-0.83) and also indicated a clinically significant change in subjective pain sensation. Mean NDI scores decreased from

Table 3. *Cervical Kinematics During Lateral Bending*

Kinematics	Pretreatment Mean	Pretreatment SD	Posttreatment Mean	Posttreatment SD	P
Quantitative Parameters					
Cross-correlation	0.47	0.41	0.63	0.46	.122
Ratio	0.43	0.32	0.41	0.33	.598
Range flexion-extension	9.44	5.08	14.61	7.99	.070
Range axial rotation	22.81	17.11	28.92	19.17	.139
Range lateral bending	68.80	15.75	80.55	17.74	.000 [a]
Qualitative Parameters					
Variability of flexion-extension	0.30	0.10	0.39	0.13	.279
Variability of axial rotation	0.42	0.21	0.46	0.18	.413
Variability of lateral bending	0.92	0.51	0.90	0.42	.181
Jerk on flexion-extension	0.08	0.03	0.08	0.02	.999
Jerk on axial rotation	0.08	0.02	0.07	0.01	.753
Jerk on lateral bending	0.10	0.08	0.10	0.01	.477

df, degrees of freedom; *SD*, standard deviation.
Means and SDs are expressed in degrees. Jerk is an absolute value (smaller values indicate a smoother movement).
[a] Level of significance with $P < .05$, paired t test, $df = 27$.

10.37 (SD = 4.47) at baseline to 6.00 (SD = 6.27) 1 week after the manipulation. This change was statistically significant ($P < .001$, 95% CI = 0.19-0.87) (Table 5).

Discussion

Three-dimensional kinematic parameters exhibited short-term effects for several qualitative and quantitative outcome variables. Specifically, thoracic HVLAT manipulation treatment led to a significant improvement in the ranges of all 3 main motion components: axial rotation, lateral bending, and flexion-extension. The posttreatment range of axial rotation and lateral bending was nearly comparable to normative data from the studies of Jordan et al[39] and Morphett et al.[41]

The decrease in the jerk index of the main motion axial rotation reveals the positive influence of HVLAT manipulation on the smoothness of active cervical movement. Unexpectedly, for flexion-extension as the main motion, the jerkiness of both flexion-extension and axial rotation did not decrease. One possible explanation might be increased co-activation of the neck muscles, as also mentioned by Sjölander et al[42]; other explanations for the unexpected change could be the exacerbation of neuromuscular reactions, as well as peripheral and spinal mechanisms resulting from HVLAT manipulation. In addition, the calculation for the main motion flexion-extension was based on a small sample size (n = 16) which may have influenced the present result. The significant change in the jerk index might therefore not represent a systematic intervention effect, because it did not occur for the 2 other main motion components (axial rotation, lateral bending).

In accordance with previous studies, a clinically significant pain reduction after treatment was observed.[27-29] Only the NDI had a statistically significant change during the 1-week follow-up measurement. A clinically significant change would require a reduction of at least 10.2 points on the NDI scale.[51,52] One reason for this result could be that the small sample size of the present study is not a correct representation of the population of acute neck pain patients, reflected in the relatively low baseline scores of disability in the present sample. Future studies should refer to the MCID in defining a minimum score of 10 points for the NDI as an inclusion criterion.

To avoid known disadvantages of electromagnetic measurement techniques—potential noise in the resulting data caused by movements of the sensors that are attached

Table 4. *Cervical Kinematics During Flexion-Extension*

Kinematics	Pretreatment Mean	Pretreatment SD	Posttreatment Mean	Posttreatment SD	*P*
Quantitative Parameters					
Cross-correlation	0.12	0.66	−0.24	0.57	.137
Range flexion-extension	110.11	20.77	118.81	18.64	.031 [a]
Range axial rotation	8.85	5.52	9.41	6.04	.129
Range lateral bending	10.40	5.23	10.15	5.17	.599
Qualitative Parameters					
Variability of flexion-extension	1.17	0.42	1.30	0.60	.627
Variability of axial rotation	0.23	0.12	0.26	0.14	.338
Variability of lateral bending	0.25	0.15	0.25	0.10	.331
Jerk on flexion-extension	0.13	0.06	0.30	0.72	.013 [a]
Jerk on axial rotation	0.07	0.01	0.13	0.22	.016 [a]
Jerk on lateral bending	0.14	0.57	0.15	0.10	.114

SD, standard deviation.
Means and SDs are expressed in degrees. Jerk is an absolute value (smaller values indicate a smoother movement).
[a] Level of significance with $P < .05$, paired *t* test, $df = 15$.

Table 5. *Subjective Pain and Functional Levels*

Scale	Baseline Mean	Baseline SD	Posttreatment Mean	Posttreatment SD	*P*
Visual analogue scale	4.05	1.71	1.71	1.29	.000 [a]
Neck Disability Index	10.37	4.47	6.00	6.27	.000 [a]

df, degrees of freedom; *SD*, standard deviation.
Means and SDs are expressed in centimeters for both scales.
[a] Level of significance with $P < .05$, paired *t* test, $df = 29$.

to the patient's skin and the attractive force of ferromagnetic substances—all ferromagnetic material was banned from the testing area, and the sensors were fixed with double-faced adhesive tape.[54,55] To reduce measurement errors between pretreatment and posttreatment a standardized sitting position was chosen including fixation of the chair, desk, and transmitter. Further, all patients received standardized movement instructions. For palpation of the bony landmarks, the same investigator marked the reference points with a pen on the skin so that similar reference frames for baseline and posttreatment measurements could be set.

An ETS (Liberty) was used to assess quantitative and qualitative movement parameters in patients with nonspecific acute neck pain. Because of technical difficulties, not all data from the 3 main motions could be analyzed (axial rotation n = 21, lateral bending n = 28, and flexion-extension n = 16). Still, the analyses of measurements made before and after the thoracic HVLAT manipulation revealed statistically significant improvements in the range of each of the 3 main motions: axial rotation, lateral bending, and flexion-extension. With respect to the qualitative parameters, results were inconsistent. Whereas for axial rotation, an increase in smoothness of the associated flexion-extension movements could be observed, there were no increases in smoothness for lateral bending and flexion-extension.

The significant changes in quantitative parameters of the main motion range were accompanied by a significant reduction in subjective pain ratings directly after the HVLAT manipulation. After 2 weeks, there still was a significant reduction in functional disability (NDI), which did not reach clinical significance. These results are in accordance with the studies of Martinez-Segura et al,[20] Cleland et al,[23] Fernández-de-las-Peñas et al,[27] and Young et al,[29] who obtained comparable results in improvement of the cervical ROM and pain reduction.

Limitations

Intervention effects could not be compared with those for a control group; thus, the results should be interpreted with caution. Possible external factors influencing the healing process cannot be eliminated. Further, because of technical problems, the intended n of 25 participants could not be obtained for all movements, increasing the chance of type I error. Further investigations with larger sample sizes and a control group are needed to verify the current findings.

Conclusion

A thoracic HVLAT manipulation led to a positive change in quantitative and qualitative aspects of 3-dimensional cervical spine kinematics in a subgroup of patients with acute neck pain. Immediately after the HVLAT manipulation, a significant improvement in the ranges of all 3 main motions and a reduction in pain experience were observed. The functional disability scores on the NDI decreased only statistically significantly within a 1-week follow-up. In addition, the manipulation affected the smoothness of motion. Because of the 1-intervention group design, external factors influencing the healing process could not be eliminated.

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Contributorship Information

Concept development (provided idea for the research): N.L.K., G.M.B., E.C.
Design (planned the methods to generate the results): N.L.K., G.M.B, E.C.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): N.L.K., G.M.B., E.C.
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Practical Applications

- In this study, 1 session of thoracic HVLAT manipulation improved both cervical ROM and smoothness in patients with acute neck pain.
- Patients' subjective pain ratings were significantly reduced directly after thoracic HVLAT treatment.
- Thoracic HVLAT manipulation achieved effects similar to those of cervical manipulation regarding pain reduction and improvement of cervical ROM.

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