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The Effect of Chronic Mild to Moderate Neck Pain on Neck Function as Measured by Joint Reposition Error and Tactile Acuity of the Cervical Dermatomes

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ABSTRACT

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The purpose of this study was to observe the joint reposition error and tactile acuity of patients with chronic mild to moderate neck pain and compare those values to healthy controls to further investigate the effect of neck pain on neck function and the need for sensorimotor training in patients with chronic neck pain. In spite of some inconsistencies in the literature and methodology, both the two-point discrimination test and the joint reposition error test can give clinicians valuable, inexpensive and quick objective data that can be used in the diagnostic portion of an examination as well as in designing and assessing change during a rehabilitation program. This study found a significant increase in neck joint reposition error (JRE) in flexion in participants suffering from neck pain when compared to healthy controls. JRE averaged $2.75° \pm 1.52°$ in flexion healthy controls and $4.53° \pm 1.74°$ in flexion in participants with chronic neck pain. Additionally, the dermatome found to be most affected by neck pain was C5. Further research is needed to examine both the effect of proprioceptive training on neck pain and the effectiveness of the two-point discrimination threshold test and the joint reposition error test as diagnostic tools and indicators of progress in the treatment of chronic neck pain.

ACKNOWLEDGMENTS

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Introduction

Neck pain is reported to effect 33% of people each year.[1] That percentage is estimated to affect 16% of people between the ages of 18 and 29 and increase with age.[1] The source of neck pain is often illusive and can come as a result of many varying pathologies. These pathologies include whiplash,[2] poor posture,[3] degenerative disorders,[4] neuropathy,[4] tumors,[5] surgical procedures,[6] and fatigue as a result of the forces of gravity on the neck muscles.[7,8] Integral to the complexity of neck pain pathology and treatment are the varying structures that comprise the neck. These structures include muscles, nerves, vessels, vertebrae, ligaments, tendons and connective tissue which combine to work synergistically to support the head.

While much is known about the causes of neck pain, less research has been done on the effect of pain on neck function. The research that has been done often varies dramatically in both methodology and outcomes, leading to inconclusive results. Pain has been reported to effect neck muscle strength,[9,10] neck muscle size and thickness,[11,12] range of motion,[13,14] joint reposition error (JRE),[15] and tactile acuity of cervical dermatomes.[16,17] Along with pain, age has also been identified as a major contributor to neck dysfunction and has been linked to decreases in neck strength,[18] muscle size, range of motion,[19] and tactile acuity.[20,21]

Evidence exists that suggests the thickness of select neck muscles in neck pain sufferers is smaller when compared to healthy controls.[22,23] Reduction in maximal isometric neck strength has also been reported in neck pain sufferers suggesting that as the muscle loses mass, in this case measured by muscle thickness, it becomes less capable of producing force.[9,10] Range of motion has also been reported to be effected by neck pain.[13,14,24,25] However, the effect of pain on joint reposition error and tactile acuity of the cervical region is less understood.

Joint reposition error[15,26] and tactile acuity[16] are both tests developed to analyze sensorimotor function. Sensorimotor function is important in maintaining the stability of posture control allowing for the movements required in performing activities of daily living such as driving, reading, and observing surrounding environments to protect against potential hazards.[26] Decreases in JRE[27] and sensation[28] have been reported in patients suffering from neck pain and are indicative of a decrease in sensorimotor function. However, while decreases have been reported, results vary between studies and normative values have not been properly established to use as a standard.

JRE is an objective measure of neck reposition sense.[29] The primary role of JRE is to represent the afferent input from the cervical region of the spine and muscle receptors measuring the ability to return to normal resting head posture.[27] It has also been mentioned as a measure of proprioception.[29,30] JRE has been reported to be higher in patients suffering from pain related symptoms as a result of whiplash.[29,31,32] However, little research has been done on chronic pain resulting from other pathologies with regards to joint reposition error. While many of these studies reported significant differences in JRE in at least one or more movement directions, the amount of variance has varied dramatically between studies.[27,32,33] The effected movement has also varied between studies.[34]

Tactile acuity measures the keenness or sharpness of the sense of touch. The most common method for measuring tactile acuity is by the two-point threshold test.[21] The validity and effectiveness of the two-point threshold test has been the subject of controversy with researchers and surgeons questioning the accuracy and repeatability of the test.[21] Inconsistencies in methodology such as pressure applied to the area with each stimulus, location of stimulus, and time interval between stimuli are some major concerns when performing a two-point threshold

test.[21] Even the orientation of stimuli has been indicated as a source of variance.[20] Little research has been done studying the effect of neck pain on tactile acuity and the research that has been done has focused primarily on the sensation of the area directly around the neck. Little research has been done on the sensation of cervical dermatomes C4 through C6 which radiate down the shoulder and in to the arm. Due to the varying methodology and results of previous studies performed to evaluate the effect of neck pain on sensation as it relates to and aids in neck function, this study will use a very precise predetermined procedure taking into account many of the mentioned shortcomings in using the two-point discrimination test.

It has been shown that strength training along with stretching has decreased pain in chronic neck pain sufferers.[8] Therapists use this information to design specific programs to help their patients regain appropriate levels of neck strength and range of motion in an effort to consequently improve neck function. Similarly, if neck sensation and/or joint reposition error are effected by neck pain, specific programs could be designed to treat these specific symptoms. The purpose of this study was to observe the joint reposition error and tactile acuity of patients with mild to moderate chronic neck pain and compare those values to healthy controls in an effort to further investigate the effect of neck pain on neck function.

Methods

Subjects

Forty subjects (22 females, 18 males) completed this study. Those subjects were divided into two groups; a pain group and a no pain group. Twenty-two subjects participated in the pain group (13 females, 9 males; age 25.5 ± 9.75 y; body mass 77.76 ± 15.56 kg; height 172.36 ± 10.19 cm). Eighteen subjects participated in the control group (9 females, 9 males; age 23 ± 5.91 y; body mass 70 ± 13.05 kg: height 174.42 ± 10.1981 cm). All subjects were recruited via flyers

placed around the campus of Brigham Young University. All subjects were required to sign a consent form approved by the IRB at Brigham Young University prior to participation in the study.

Inclusion Criteria

Subjects were assigned to a group based on their Neck Disability Index score and duration of neck pain. All participants scoring above an 8 were assigned to the neck pain group. Those scoring a 4 or below were assigned to the control group. All neck pain subjects were required to have at least 12 wk of neck pain to be included in the neck pain group. Visual analogue scale (VAS) scores were also collected as an indicator of pain in both groups. Each group's pain indicator scores in Table 1. The researcher that performed each of the measurements was blind as to the group for each participant to avoid any researcher bias.

Measures of Neck Function

Cervical JRE and two-point discrimination thresholds were taken on all participants in both groups. Cervical range of motion and isometric neck strength were measured to help describe the population but not used in the analysis.

Two-Point Discrimination

Two-point discrimination thresholds were measured at each dermatome from C3-C8. Each dermatome was measured one both sides. The site at which each dermatome was tested followed procedures established by Voerman et al.[35] Due to the limitations that have been identified with two-point discrimination, the following parameters were followed to limit inconstancies between measurements. All measurements were taken with a vertical orientation. The tips of the baseline two-point discriminator device were filed slightly to create a more blunt edge to avoid any sensation of pain. The threshold was determined by the smallest distance

between the two stimuli that the participant could still detect two distinct stimuli rather than just one. The distance between the two points started at 10 mm for C6-C8, 30 mm was the starting threshold for C3-C5 however. As the threshold for C3-C5 dermatomes was found to vary more significantly in pilot studies, the distance was increased from 30 mm until the first correct response of two distinct stimuli before the testing procedure started. Adjustments to the distance between stimuli was made as follows: for each correct answer of one or two stimuli the distance between the two points was reduced by 2 mm and for each incorrect answer the distance was increased by 1 mm. Participants were given one or two stimuli until five incorrect answers were given following the initial correct identification of two distinct stimuli. Both the examiner and participant were seated with their arms supported on a table. When two stimuli were presented, care was taken to make contact at the same time with both points. Tips were blunted to decrease the confusion between pain sensation and tactile acuity. The pressure applied to the skin was kept to about 10 grams or that equal to the first blanching of the skin.[21] The following landmarks were used to identify each cervical dermatome measured: C3—3 cm above the mid-clavicular line; C4—anterior edge of the acromion; C5—the lowest point of the deltoid insertion; C6—the thenar eminence; C7—volar surface of the base of the third digit; and C8—volar surface of the base of the fifth digit.[35]

Joint Reposition Error

To measure JRE a strap with a laser attached on the top was placed on each participant's head. Each participant was then positioned exactly 90 cm from a mobile target placed on the wall. The target was mobile so it could be properly adjusted for each participant to start with the laser in the middle of the target. Glasses were worn by each participant to occlude their vision. The participant was then strapped into a straight backed chair and asked to place their head in

neutral resting position by looking straight at the wall in their perceived most comfortable position. The target was then aligned with the laser point on the center mark. The participant was then asked to maximally flex their neck and then return to starting position. The point where the laser came to a rest on the target was marked representing the JRE. Following the recording of each mark, the target was covered with an identical target without any marks so the participant was blinded from their results. The participant was then aided in returning their head back to the start position by taking off the glasses and returning to starting position. The same process was repeated with the participant extending the neck, rotating the neck to the left and rotating the neck to the right representing both horizontal and vertical movements. This process was repeated three times in each direction. No practice trials were allowed and the mean of the 3 trials was used in the analysis.

Neck Range of Motion

Range of motion measurements were taken using a CROM 3 Accelerometer (Performance Attainment Associates, Lindstrom, MN). A straight backed chair with straps was used to secure the participant's trunk firmly to the chair with the back flat against the back of the chair. Each measure was taken three times and an average of the three attempts was analyzed. Neck flexion range of motion was measured with the position of the neck at the point where the sagittal plane meter read zero. The participant was then instructed to flex the neck to make a double chin as far as possible. The measurement was taken from the sagittal plane meter. Neck extension range of motion was measured with the neck at the point where the sagittal plane meter read zero. The participant was then instructed to tilt the head back as far as possible. The measurement was read on the sagittal plane meter and then recorded. Right lateral flexion was measured with the neck in position where both the sagittal plane and lateral plane meters read

zero. The participant was instructed to look at a single point on the wall to avoid rotation. The participant was then instructed to flex the head to the right by bringing the right ear down to the right shoulder and the measure was read from the lateral flexion meter and recorded. This process was repeated on the left side to measure left lateral flexion range of motion. To measure rotation the magnetic yoke pointing north was required. Each participant was instructed to focus on a horizontal line on the wall to avoid head tipping. The participant was then instructed to position the head where the lateral and sagittal plane meters read zero. The rotation meter was then set to zero. For left rotation the participants were instructed to rotate the head to the left by looking over the left shoulder. The reading was observed on the rotation meter and recorded. This process was repeated on the right side to measure right rotation. During all measures the shoulder was monitored for elevation and rotation by lightly placing a hand on the shoulder and correcting manually any head motion outside of the desired plane.

Neck Isometric Strength

Neck isometric strength was measured using a strain gauge (Micro ergoFET2, Hoggan Scientific LLC, Salt Lake City, UT). Neck flexion, extension, left and right lateral flexion, and left and right rotation were measured. For each measurement the strain gauge was firmly attached to a 2x8 inch wood mount which extended perpendicular from the wall. The mount could be elevated up and down to match the individual height of each participant. All measurements were taken with the participant in the straight back chair with the torso firmly secured against the back of the chair. Over the course of 3 sec the participants were instructed to slowly increase the pressure applied to the strain gauge, finishing with a maximal effort. Flexion was measured with the forehead firmly against the strain gauge. The participant was then instructed to flex the neck against the strain gauge. Extension was measured with the posterior

aspect of the head just above the external occipital protuberance placed firmly against the strain gauge. The participant then extended the neck into the strain gauge. Right lateral flexion strength was measured by placing the gauge against the right side of the participant's head just above the right ear and a maximal contraction was performed. This process was repeated on the left side for left lateral flexion. Each strength measurement was performed 3 times and the mean of those three trials was reported for informational data.

Results

A standard independent two-sample t-test with equal variance was reported for each of the six cervical dermatomes and for each of the four movements with joint reposition error. A Bonferroni correction was performed following the analysis to account for each of the ten measurements performed on each participant. This provided for a significance level of 0.005 uncorrected, which translates to a Bonferroni corrected significance level of 0.05. Means and standard deviations were provided for neck range of motion and neck maximal isometric contractions for discussion purposes.

The results of the two-point discrimination test are displayed in Table 2. It was found that the largest difference in sensation was at the C5 dermatome between the pain group and the no pain group. While none of the levels showed a significant difference, the mean two-point discrimination threshold was higher in the pain group in each of the six measured dermatomes.

Results for JRE can be found in degrees in Table 3. The degrees of error were derived by calculating the arc tangent of the distance between the center point and the marking on the target in centimeters divided by ninety centimeters. Neck flexion was found to vary significantly between the no pain and pain groups; however, right rotation, left rotation, and extension showed no significant differences between the two groups following the Bonferroni correction.

Maximal isometric strength measurements were taken to help describe the population but were not used in the analysis. The results are shown in Table 4. Range of motion measurements were also taken to help describe the population and are shown in Table 5.

Discussion

Sensation and neck position sense are two of the most important functions of the neck. As the body's center for controlling balance is located within the inner ear, neck position sense is vital in the control and maintenance of balance.[36] Increased understanding of the effect neck pain has on neck position sense has led to a recent increase in the study of vestibular rehabilitation as a treatment of neck pain.[37] This suggests that neck pain sufferers may benefit from training exercises designed to improve neck position sense.[37-39] The JRE test offers an inexpensive and quick method of clinically measuring neck position sense. Neck sensation is also a vital component in neck function and allows for the sense of touch to be perceived. The two-point discrimination threshold test offers an inexpensive and rapid method for measuring the tactile acuity of the associated dermatomes of the neck within a clinical setting.[40]

 Reported unreliability and variance in testing procedures has led to a decline in the use of two-point discrimination in the clinical setting.[21] The use of joint reposition error testing had also declined but has recently enjoyed a resurgence.[38] However, in spite of some inconsistencies in the literature and methodology, our results suggest both the two-point discrimination test and the JRE test can give a clinician valuable objective data that can be used in the diagnostic portion of an examination as well as in designing and tracking change during the rehabilitation program.

With respect to tactile acuity it has been reported that a threshold less than 5 mm on dermatomes C6-C8 is normal and marks no decrease in sensation.[21] We found no difference in tactile acuity between groups for dermatomes C6-C8. All our thresholds were within accepted

norms. However, a search of the literature revealed no normative values reported for cervical dermatomes C2-C5. Our results of the threshold values for these dermatomes were from 5 to 11 times greater than those of C6-C8. We found no difference between groups for C3 dermatome, a trend toward significance appeared for C4 ($p = .0778$) and approached significance for C5 ($p = .0089$). Some research has been done with monofilaments to help determine sensation thresholds across all cervical dermatomes.[35] This research has shown that age leads to a decrease in sensation independent of pain.[35]

However, as observed in this study, it appears differences in two-point discrimination between pain sufferers and healthy controls may be evident. Two-point discrimination threshold at the C5 level approached significance suggesting that the effect of neck pain on tactile acuity is not limited to the area directly surrounding the neck, but may also effect the upper arms. Indeed, we found no difference between groups in the tactile acuity threshold for the dermatomes directly associated with the neck C3 and C4. This evidence suggests that while evaluating neck sensation of an individual following a neck injury, in the presence of mild or moderate neck pain, it is equally if not more important to measure the sensation of the surrounding dermatomes and not limit the examination to just those dermatomes surrounding the neck.

Revel et al.[27] in the initial study examining JRE reported normative values for healthy individuals in vertical movements to be $3.37° ± .73$ and $3.5° ± .82$ for horizontal movements. Pain sufferers were reported to have vertical JRE of $5.47° ± 1.75°$. However, little difference was found between the pain and no pain groups with horizontal movements with a reported error of $3.37° ± .73°$ in the pain group. Since the work by Revel et al.,[27] several studies have been performed to establish normative values for JRE on each of the three cardinal planes both in healthy controls and in patients suffering from neck pain. However, a broad variance still exists

with reported norms for healthy controls ranging from 1.9° to 3.5° and reported norms for pains

sufferers ranging from 3.37° to 5.9° depending on the study and on which cardinal plane

movement was examined.[27,29,30,33,34,41] Sterling et al.[30] examined right rotation, left rotation and

extension in three groups of participants with varying levels of neck pain to help determine pain

specific normative values for varying pain levels. They reported normative values ranging from

3.0° in the recovered group to 4.8° in the moderate to severe pain group. The JRE of the no pain

control group for our study ranged from 2.75° for flexion to 4.08° in left rotation. Flexion and

right rotation fell within the established normative values, extension and left rotation were

slightly above. Our pain group varied from 3.38° for right rotation to 5.77° for extension. All our

pain group JRE were within the reported norms. It is expected that age would affect JRE as both

range of motion[42] and neck strength[18] have been shown to decrease with age suggesting that the

varying age of participants in each of these studies may play a role in the varying results in

reliability and normative values. Teng et al.[43] examined the effects of age on cervical JRE. They

reported that there was a significant difference in JRE in middle aged adults when compared to

young adults regardless of neck pain. We attempted to control for the variances in reposition

error due to pain level, duration of pain, age and variance between examiners by designing a

study in which all measurements were taken by the same examiner, participants were age

matched between groups and all participants had to have experienced pain for a minimum of 12

wk prior to participating in the study. Our groups (pain and no pain) were homogeneous based

on NDI scores. After controlling for the above sources of variance, it was found that flexion neck

reposition error was significantly worse in the pain group than the healthy control group.

However, no significant group difference was found in JRE in the horizontal movements of right

and left rotation, suggesting that pain has a greater effect on vertical movements than horizontal

movements. This finding is consistent with much of the literature and suggests that training should be used which incorporates actions on a vertical axis.[27,38]

Traditional physical therapy programs use a combination of strength training and range of motion exercises to treat patients with neck pain.[44] It has been shown that strength training along with stretching has decreased pain in chronic neck pain sufferers.[45-48] Therapists use this information to design programs to help their patients regain appropriate levels of neck strength and range of motion in an effort to improve neck function. Similarly, neck sensation and JRE are effected by neck pain. To counteract the negative effects of pain on tactile acuity and cervical JRE, a program could be designed to treat these specific symptoms. Exercises involving neck position sense and tactile acuity could be incorporated as part of treatment procedures when treating patients suffering from chronic neck pain.

Traditional physical therapy protocols has been reported to help with patients suffering from chronic neck pain[44]; however, the effect of proprioception training is less understood.[49,50] Jull et al.[38] examined the effect of proprioception training in patients with chronic neck pain and measured their results using JRE. They compared conventional proprioceptive training with craniocervical flexion exercises. Jull et al.[38] reported significant decreases in JRE, perceived neck pain and perceived disability in both groups. Due to the paucity of research in this area further investigation is needed to determine the effectiveness of neck position sense and tactile acuity training programs in the treatment of chronic neck pain. Proprioceptive training is an invaluable component of rehabilitation in the recovery process of major joints including the shoulder,[51] knee,[52] hip,[53] and ankles[54] and could potentially be incorporated into cervical joint rehabilitation pending further examination.

While normative values provide a standard by which clinicians can compare current patients to both healthy controls and previously documented pain sufferers, perhaps an additional beneficial application for both the two-point discrimination test and joint reposition error is as a measure of pretest and posttest measures to help chart progress in patients suffering from neck pain who are undergoing therapy.

Limitations of this study include variation in the duration and intensity of pain for each participant in the pain group, compared with other studies which have reported greater differences in pain levels between healthy controls and pain sufferers. All participants had experienced neck pain > 12 wk, but no additional data was gathered with regards to duration of chronic pain. Additionally, we averaged the two-point discrimination threshold bilaterally which may have lessened the impact of any unilateral impairment which may have been present.

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Table 1 Pain Indicators

	Group		P Value
	No Pain	Pain	
Visual Analogue Scale (mm)	3.83 ± 6.86	28.68 ± 15.24	< .0001
Neck Disability Index (1–50)	1.06 ± 1.21	10.73 ± 3.21	< .0001

Table 2 Tactile Acuity Threshold (mm)

Dermatome	Group		P Value
	No Pain	Pain	
C3	24.0 ± 7.43	27.41 ± 6.37	.1259
C4	29.25 ± 7.39	35.43 ± 12.81	.0778
C5	35.25 ± 10.06	45.86 ± 13.54	.0089
C6	3.86 ± 1.66	4.02 ± 1.28	.7306
C7	4.64 ± 1.77	5.02 ± 2.06	.5361
C8	4.36 ± 1.40	4.90 ± 1.64	.2762

Table 3 Neck Reposition Error (degrees)

Movement	Group		P Value
	No Pain	Pain	
Flexion	2.75 ± 1.52	4.53 ± 1.74	.0015*
Extension	3.78 ± 1.95	5.77 ± 2.73	.0133
Right Rotation	3.43 ± 1.45	3.38 ± 1.53	.9239
Left Rotation	4.08 ± 1.71	5.47 ± 3.77	.1558

*Statistically significant P-value with Bonferroni correction

Table 4 Isometric Neck Strength (kg)

Movement	Group	
	No Pain	Pain
Flexion	12.63 ± 6.28	11.33 ± 6.81
Extension	14.77 ± 5.80	13.45 ± 7.55
Right Lateral Flexion	12.03 ± 5.86	10.57 ± 5.35
Left Lateral Flexion	12.24 ± 5.34	10.84 ± 5.44
Right Rotation	10.55 ± 5.70	9.35 ± 3.70
Left Rotation	10.24 ± 5.31	8.87 ± 4.00

Table 5 Neck Range of Motion (degrees)

Movement	Group	
	No Pain	Pain
Flexion	62.15 ± 10.18	55.68 ± 11.62
Extension	74.07 ± 10.33	74.82 ± 18.03
Right Lateral Flexion	44.53 ± 8.10	45.63 ± 11.23
Left Lateral Flexion	41.97 ± 8.77	45.41 ± 9.00
Right Rotation	57.76 ± 5.45	59.01 ± 8.63
Left Rotation	57.42 ± 7.39	57.86 ± 9.33