Immediate Effects of Cervical Spine Thrust Joint Manipulation on Gait Parameters in Individuals with Neck Pain

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IMMEDIATE EFFECTS OF CERVICAL SPINE THRUST JOINT MANIPULATION ON
GAIT PARAMETERS IN INDIVIDUALS WITH NECK PAIN

By
Marc John Anthony D. Albano
Emily M. Blok
Beau H. Gronert
Ryan T. Masuda

A doctoral project submitted in partial fulfillment
of the requirements for the
Doctor of Physical Therapy

Department of Physical Therapy
School of Allied Health Sciences
Division of Health Sciences
The Graduate College

University of Nevada, Las Vegas
May 2018
This doctoral project prepared by

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Beau H. Gronert

Ryan T. Masuda

entitled

Immediate Effects of Cervical Spine Thrust Joint Manipulation on Gait Parameters in Individuals with Neck Pain

is approved in partial fulfillment of the requirements for the degree of

Doctor of Physical Therapy
Department of Physical Therapy

Emilio Puentedura, Ph.D.  
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Daniel Young, Ph.D.  
Research Project Advisor

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Chair, Department of Physical Therapy

Kathryn Hausbeck Korgan, Ph.D.  
Graduate College Dean
Purpose/Hypotheses: 1. To investigate for any change in gait parameters in individuals with neck pain while walking with different functional neck conditions immediately following cervical thrust joint manipulation (TJM) versus a sham intervention. 2. To investigate any association between Global Rating of Change (GROC) scores and gait parameters immediately following cervical thrust joint manipulation versus a sham intervention. The hypotheses were that, a) cervical TJM would have an immediate effect on gait parameters during walking with the neck in at least one of three conditions (neutral, flexion/extension and rotation) among individuals with neck pain; and b) higher scores on the GROC would be associated with improved gait parameters post-intervention.

Subjects: Convenience sample of 40 individuals (30 female; mean age 24.5 ± 6.78 years) with neck pain. To qualify, subjects had to have a score >0 on the question of pain intensity in the neck on the Neck Disability Index (NDI) questionnaire and have no contraindications or precautions for cervical TJM.

Materials/Methods: Subjects walked on a Zeno Walkway under the following conditions: 1) head in neutral; 2) head rotating from side-to-side, and 3) head nodding up and down. After completing 30 practice trials (10 in each condition), pre-intervention trial 1 gait parameters were recorded for each of the three neck conditions in a randomized order. After a 5-minute rest period, pre-intervention trial 2 was conducted for each condition in same order as trial 1. Subjects then received one of two randomly assigned interventions: cervical spine TJM or active cervical rotation. Immediately after the intervention, the subject returned to the Zeno Walkway for the post-intervention trial 3 in each of the three conditions, in the same order as their previous trials. Gait parameters of average step length, stride length, stride width, velocity, and cadence
were analyzed using a 2x2 repeated measures ANOVA (of trials 2 and 3), as well as independent and paired t-tests, to determine if there were any significant changes based on intervention when comparing TJM to sham groups.

**Results:** The results of the 2x2 ANOVA revealed significant interactions between group and time on average gait velocity (p=0.008), step length (p=<0.001), and stride length (p=0.009) when the head was in a neutral position. The TJM group experienced significant increases from pre to post-intervention as shown by paired samples t-test for average gait velocity (p=0.003), step length (p<0.001), and stride length (p=0.008). The sham group however, experienced no significant change in gait velocity (p = 0.290), average step length (p = 0.299), and stride length (p = 0.292). There was also a significant decrease in the Numeric Pain Rating Scale (NPRS) (mean decrease of 1.25; p=0.003) and the group that received cervical TJM reported an improved perception of change demonstrated by an average increase in GROC score by 2.85 (p=0.001).

**Conclusions:** Although our results demonstrate a statistically significant improvement in three gait parameters following TJM while walking with the neck in a neutral position, the improvements are not clinically significant. At this time, there is no evidence-based indication for the clinical use of cervical TJM to improve gait parameters in individuals with neck pain. Our findings cannot confirm clinical significance for reduction of neck pain with cervical TJM based on NDI, NPRS, or GROC questionnaires.
ACKNOWLEDGEMENTS

This research study was made possible by the UNLVPT Student Opportunity Research Grant (SORG). The authors would like to thank Dr. Emilio Puentedura for his guidance as the principal investigator of this study. They would like to also acknowledge Dr. Daniel Young, Dr. Szu-Ping Lee, Dr. Kai-Yu Ho, and Dr. Jing Nong Liang for their involvement and aid throughout, as well as the UNLV Physical Therapy program for allowing us to use the Zeno Walkway. The authors declare that they have no competing interests or conflict of interest directly relevant to the content of this study.
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INTRODUCTION

Background

According to the National Centers for Health Statistics, 15% of adults who have pain report it in their neck.\(^1\) Neck pain is a common occurrence in the American population with an average of 213 out of every 1,000 people self-reporting neck pain and is a frequent cause of chronic pain with a yearly prevalence ranging from 30% - 50%.\(^2\) The perceived disability of neck pain has been shown to interfere with activities of daily living and is reported as activity-limiting pain in up to 11.5% of the American population reporting neck pain.\(^2\) With the significant prevalence of neck pain, gaining a greater understanding of its causes, implications, and treatments is essential for health care providers to improve outcome measurements and quality of care for individuals experiencing neck pain.

Mechanical neck pain is made better or worse with movement, activities or postural changes. Mechanical neck pain is typically thought to stem from excessive or abnormal stresses on the vertebral structures and musculature of the cervical spine that are commonly associated with poor posture during standing or sitting, as well as poor lifting techniques.\(^3\) Such stresses may lead to changes in the mobility of vertebral facet joints, as well as sensitivity of mechanoreceptors and the afferent signals associated with vestibular, somatosensory, and visual systems.\(^4\) The symptoms resulting from these issues include reduced functional movements of the cervical spine and increased postural sway from 130-170% when compared to individuals without neck pain.\(^5\) These disabilities are not limited to neck movements while the individual is sitting or standing; current research indicates that there is a correlation between the presence of
neck pain and impaired gait.6–9 This relationship may suggest functional limitations among people with neck pain during ambulatory tasks such as shopping, traveling, hiking, and many other activities of daily living.

Thrust joint manipulation (TJM) is a manual therapy technique performed by physical therapists.10 Passive physical therapy mobilization and TJM vary in speed and amplitude. TJM is performed at a high velocity and low amplitude.10 Physical therapists have practiced TJM since the early 20th century and are currently taught in the United States at a doctoral level.10 The most recent clinical practice guideline on neck pain from the Journal of Orthopaedic and Sports Physical Therapy gave cervical spine TJM and mobilization an “A” rating based on current evidence. This is the highest grade of recommendation that an intervention can receive, suggesting that clinicians should consider utilizing cervical spine TJM and mobilization with other evidence-based treatment methods to more effectively reduce neck pain, headache, and disability.11

Previous studies have shown that TJM affects motion of the spine by altering the biomechanical function of spinal facet joints.12 However, it is also important to consider the neurophysiological effects of TJM. Although these neurophysiological responses cannot be measured directly, associated responses of hypoalgesia and sympathetic activity following TJM suggest involvement of the periaqueductal gray and dorsal horn of the spinal cord.12,13 There have also been chemical reactions observed in the body following TJM, with levels of serotonin, B-endorphins, and endogenous cannabinoids increased following TJM, as well as a decrease in inflammatory cytokine levels.12,14
A previous study by Uthaikhup et al. compared gait parameters of 20 subjects with neck pain for duration longer than three months and 20 controls with no reported pain or disability. They reported that subjects with chronic neck pain who were instructed to ambulate at a comfortable velocity with head movements had significantly decreased gait velocity, step width, step length, and stride length, when compared to the control group (all $p < 0.05$), while step time, stride time, and cadence had no significant change (all $p > 0.05$). These alterations in gait performance were observed during walking with cervical rotation and nodding into flexion and extension for these parameters when compared to a pain-free control group. When the instruction changed to maximal walking speed with head positioned in neutral, significant interactions and independent t-tests went on to show that subjects with neck pain had slower gait velocity, shorter step length and narrower step width when compared to the controls (all $p < 0.05$). The researchers concluded that structural impairments of the cervical spine might affect symmetry and velocity of gait. They suggested that interventions to improve the structural impairments of the cervical spine needed to be further investigated.

An article by Nystrom et al reported gait parameters before and after surgeries intended to relieve mechanical neck pain in 12 subjects with whiplash-related cervical spine injury. They analyzed gait parameters including speed, cadence, and step length, as well as subjective pain measurements pre and post intervention. Subjects from their study reported significantly lower pain ratings with an average decrease of 3.7 on the visual analog scale (VAS) after surgery ($p=0.002$). The researchers also found statistically significant increases in average gait speed of 13.9 centimeters/second ($p=0.007$), average step length of 5.2 centimeters/step ($p=0.009$), and
average cadence of 6.2 steps/minute, though it was not stated whether the instruction for walking speed was maximal or submaximal for these trials.⁷

Although our study did not specifically examine elderly individuals, some of the findings from research done on this population may be generalized to other groups. According to Cesari et al, elderly patients with neck pain have a significantly slower self-selected gait speed (p=0.02), slower cadence (p=0.04), and a longer gait cycle duration (p=0.04) when compared to elderly patients without neck pain.⁸ They concluded that gait speed of less than 1 meter/second identifies older individuals as a high risk of poor health-related outcomes due to impairments in functional mobility, including an increased risk for falling.⁸,¹⁵,¹⁶ Kendall et al suggests that cervical TJM may be a valuable treatment option for individuals in this population who have neck pain and resulting balance deficits based on functional improvements and perceived changes in level of pain and disability after implementation.¹⁷

In a previous study conducted at UNLVPT, researchers found that performing cervical TJM on subjects with neck pain significantly increased gait velocity, but had no appreciable effects on other gait parameters.¹⁸ Their conclusions were limited by study methodology that did not allow for separation of improvement subjects could have achieved from motor learning due to practice. The result was that nearly all subjects, regardless of neck pain or treatment intervention provided, experienced increases in gait velocity and stride length.¹⁸

Our study investigates previous findings that cervical TJM reduced pain immediately after intervention.¹¹,¹²,¹⁴ However, since there is extensive evidence for the effectiveness of TJM on
pain reduction, we also aimed to investigate functional improvements following cervical TJM. The functional activity investigated was walking in a straight path with and without everyday head and neck movements.

**Project Aims and Hypotheses**

1. To investigate for any change in gait parameters in individuals with neck pain walking with different functional neck conditions immediately following cervical thrust joint manipulation (TJM) versus a sham intervention. 2. To investigate any association between Global Rating of Change (GROC) scores and gait parameters immediately following cervical thrust joint manipulation versus a sham intervention. The hypotheses were that a) cervical TJM would have an immediate effect on gait parameters during walking with the neck in one of three conditions (neutral, flexion/extension and rotation) among individuals with neck pain; and b) higher scores on the GROC would be associated with improved gait parameters post intervention.

Aim 1: To investigate for any change in gait parameters in individuals with neck pain walking with different functional neck conditions immediately following cervical TJM versus a sham intervention.

Hypothesis 1: Cervical spine TJM will result in immediate effects on gait parameters, including an increased gait velocity, increased step length, increased stride length, decreased stride width, and/or increase in cadence both with and without neck movements for individuals with neck pain.
Aim 2: To investigate any potential association between the effect of Global Rating of Change (GROC) scores on gait parameters immediately following cervical TJM versus a sham intervention.

Hypothesis 2: There will be a significant change in gait parameters in individuals with neck pain who have a positive GROC score compared to those with an absent or negative GROC score post-intervention.
METHODOLOGY

Subjects

We recruited a convenience sample of 40 subjects with mechanical neck pain. Subjects were recruited to participate through UNLV affiliated avenues such as the university e-mail system, fliers posted on UNLV campus, and recruitment in UNLV classes. Subjects who responded to advertisements were screened for eligibility to participate in the study. The inclusion criteria included: current mechanical neck pain (recording a score >0 on section 1, pain intensity, of the NDI questionnaire), age between 18-70 years, a Neck Disability Index (NDI) score of at least 10/50, and a willingness to participate in the study. Exclusion criteria included: history of neck whiplash injury; physician diagnosis of cervical spine stenosis or presence of symptoms such as radicular pain, pins and needles, or numbness peripherally in both arms; presence of central nervous system involvement such as changes in sensation in the hands, muscle wasting in the hands, impaired sensation of the face, altered taste, or presence of abnormal reflexes; evidence of neurological signs consistent with nerve root entrapment; prior surgery to the neck or upper back; a medical condition that could influence their assessment of pain ie, taking analgesics, sedatives, history of substance abuse, or cognitive deficiency; diagnosis from a physician of fibromyalgia syndrome; and potential or confirmed pregnancy. Subjects were also excluded if found to possess any “red flag” contraindications to cervical TJM, ie, a bone fracture, metabolic diseases, Rheumatoid arthritis, osteoporosis, severe atherosclerosis, prolonged history of steroid use, history of a tumor, ligamentous instability, or positive screening for vertebral artery insufficiency.
Figure 1
Procedural flow chart for complete duration of subject session and data collection.
Prior to testing

Following screening and prior to physical testing or intervention, all subjects were given the following questionnaires:

1. Neck Pain Medical Screening Questionnaire (NMSQ): The NMSQ was the first questionnaire completed by the subjects. The NMSQ screens for ‘red flags’ (i.e. rheumatoid arthritis, osteoporosis, cancer, numbness and tingling down the arms, prolonged use of steroids). The NMSQ also provided a screening for any vestibular dysfunction, as it asks about dizziness, lightheadedness, or ringing in the ears experienced by the subject.

2. Numeric Pain Rating Scale (NPRS): The NPRS is an 11-point numeric scale that was used to measure pain intensity (test-retest reliability: 0.96, correlation coefficient: 0.86-0.95). The left side of the scale indicates a score of 0 with the phrase “no pain”, and the right indicates a score of 10 and the phrase “worst imaginable pain.” Patients were asked to rate their current level of pain, as well as their worst and least amounts of pain in the previous 24 hours. The minimal detectable change (MDC) for the NPRS is reported as 1.3 points and the minimal clinically important differences (MCID) has been reported as 2.1 points.

3. Neck Disability Index (NDI) - The Neck Disability Index is a widely used disability scale specific for patients with neck pain (test-retest reliability: 0.89, correlation coefficient: 0.60-0.70). The NDI consists of 10 items addressing different functional activities. Each of the functional activities is scored from 0 to 5, with a maximum score of 50 points possible. A higher score indicates more difficulty with the functional activities, and a lower score indicates less difficulty with the functional activities. The MDC for the NDI is 5 points out of 50 whereas 7 points out of 50 was recommended for the MCID. The NDI has been reported as a reliable and valid outcome measure for patients with neck pain.
4. Global Rating of Change (GROC) - This questionnaire was provided only once: after the post intervention gait measurements. The GROC is a 15-point scale that describes perceived changes before and after intervention. The scale ranges from -7 (“a very great deal worse”) to 0 (“about the same”) to +7 (“a very great deal better”). Scores of +4 and +5 indicate moderate improvement following intervention, and scores of +6 and +7 indicate large changes following intervention. Patients who rated their perceived recovery on the GROC as “a very great deal better”, “a great deal better”, or “quite a bit better” (i.e. a score of +5 or greater) were considered to have experienced dramatic improvements. The MDC for the GROC has been reported as a 3-point change from baseline.22,23

All subjects were provided yoga socks to enable consistent, non-slip footwear while walking across the Zeno Walkway. The Zeno Walkway was positioned in the lab with 3 feet of space cleared at the beginning and end of the mat. This allowed subjects to maintain their self-selected gait speed without acceleration or deceleration occurring during data analysis.

**Practice Trials**

Prior to data collection, all subjects performed 10 practice trials in each of the functional neck conditions, for a total of 30 practice trials traversing the walkway. The subjects traversed the walkway at a self-selected pace, which had to be greater than or equal to community ambulation gait speed of 0.8 m/s or the subjects were instructed to perform the practice trial again under the following functional neck conditions: 1) head sustained in neutral, forward position, 2) head rotating from side-to-side as if checking blind spot, and 3) head nodding up and down as if
looking from feet to ceiling directly above. In this study, we allowed the subjects to use a self-selected speed while standardizing the amount of head movement with visual cuing. The purpose of these practice trials was to allow the subjects to be comfortable with walking on the Zeno Walkway while providing a standardized amount of practice, and to cue the subjects to perform their maximum active cervical rotation or flexion/extension consistently.

To standardize the functional neck movements while walking on the Zeno Walkway, all of the subjects were given the same instructions. For the neutral position, subjects were told to walk as normally as possible at their own self-selected speed. For the side-to-side rotational movements, pieces of construction paper were placed on both sides of the Zeno Walkway, equally spaced apart, level with the subjects’ eyes. The subjects were told to traverse the Zeno Walkway at their own self-selected speed, while rotating their head side-to-side as far as possible as if checking their blind spot, using the construction paper for reference. For the flexion and extension condition, subjects were told to traverse the Zeno Walkway at their own self-selected speed while looking up to the ceiling and down at the floor as far as possible. Though the subjects were required to continuously perform their neck movements (i.e. no pauses in the center), there was not a requisite minimum number of cervical rotations or flexions for each trial. If a cervical movement was missed or included a pause, the verbal commands were repeated, and the data was collected on the next trial.
Pre-Intervention Data Collection

During the data collection phase, subjects traversed the walkway three times for each condition, and the second of the three trials was used for the measurement (pre-intervention #1). The Zeno Walkway with Protokinetics software was used to measure the gait parameters. These parameters included: step length, stride width, stride length, velocity, and cadence. After five minutes of rest, the subjects’ gait parameters were measured again using the same neck condition order (pre-intervention #2).

Figure 2
Subjects started each trial behind a taped line, three feet behind the beginning of the Zeno Walkway to allow for acceleration to comfortable walking speed.
Figure 3
During neck-rotation trials, subjects turned their head as far to the left and right as possible, with colored papers being used for reference.
Figure 4
During neck-flexion trials, subjects were cued to look up and down as far as possible at a comfortable rate.

Interventions
Immediately upon completion of the pre-intervention walking trials, the subjects underwent one of two randomized interventions. Subject randomization was assigned via computerized random number generator with each subject being identified by a participant number and randomly assigned to group 1, TJM intervention, or group 2, sham intervention. The TJM intervention was a high-velocity, low amplitude manipulation to the cervical spine. Subjects underwent screening tests for vertebral artery insufficiency and laid supine on a treatment table. The TJM was performed on the spinal segment with the least mobility determined by the researcher. The sham
intervention was an active cervical rotation repeated five times to each side while supine.

Figure 5
The sham intervention consisted of AROM to each side without researcher contact.
Figure 6
The intervention consisted of a cervical manipulation to each side.

Post-Intervention Data Collection

During the interventions, the researchers responsible for leading subjects through the trials and measuring gait parameters on the Zeno Walkway (data collection researchers) left the treatment room for blinding. Furthermore, the researchers who performed the interventions or provided the measurement forms (intervention researchers) did not have access to the Zeno Walkway data. Immediately after the interventions, the data collection researchers returned and led the subject through post-intervention data collection. The subjects were given the same instructions and performed gait trials in each of the three neck conditions just as during the pre-intervention data collection. The subjects were not told which intervention they received until data collection was complete. Following all gait trials, the subjects completed the GROC, NPRS, and NDI.
**Data Analysis**

The Zeno Walkway with Protokinetics software was used for data collection of gait parameters. All gait measurements were averaged, combining left and right. While several measurements can be taken, the gait parameters of interest were those relating to average velocity, cadence, step length, stride length, and stride width.

To ensure there were no significant differences in initial gait parameters in pre-intervention #1 between groups (TJM group vs sham group), we conducted independent t-tests under three walking conditions: walking with head in neutral, walking while flexing and extending the neck, and walking while rotating the neck left and right. Next, gait parameters of pre-intervention #1 and #2 were compared within groups using paired samples t-test to ensure that motor learning within both groups had plateaued from practice trials. We then used 2x2 repeated measures ANOVAS to determine if there were significant differences in gait parameters associated with group (TJM or sham) and time (pre-intervention #2 to post-intervention). The 2x2 ANOVA was selected over 2x3 ANOVA, which omits pre-intervention #1, to focus on the immediate effects of the intervention on gait parameters. The independent variables were time (pre-intervention #2 and post-intervention) and group (TJM and sham) and the dependent variables were the gait parameters. If a significant interaction was found between time and group on any of the gait parameters under any of the neck conditions in the 2x2 ANOVA, an independent t-test comparing pre-intervention #2 and post-intervention data between groups and a paired samples t-test comparing pre-intervention #2 to post-intervention data within a group were performed to identify significant changes or differences between time-points and groups.
The questionnaires that were completed after the intervention were compared to the
questionnaires completed prior to the intervention to run statistical analysis on the subjects’
perceived change. To determine if the intervention influenced subjective outcome measures, we
ran analyses on the GROC, NPRS, and NDI. First, we used independent t-tests to compare pre-
intervention NDI and NPRS scores of the TJM vs sham groups. Next, we conducted independent
t-tests comparing the difference in scores (post-intervention score subtracted from pre-
intervention score) for the NDI and NPRS. Since the GROC was only taken after the
intervention, only one independent t-test, comparing TJM vs sham, was needed.

Finally, to determine if changes in GROC (regardless of group) were associated with gait
parameters, the subjects were split into two groups: individuals with a GROC score greater than
or equal to +1, and individuals with GROC score less than or equal to 0. Then a 2x2 repeated
measures ANOVA for pre-intervention #2 and post-intervention was conducted to measure the
immediate effects of the perceived level of change in overall neck condition on gait parameters.
RESULTS

Pre-Intervention Measurements

There were no significant differences between the two groups in demographic information (gender, age, height, weight, and duration of symptoms), pre-intervention subjective survey results, or pre-intervention #1 gait parameters (all \( p > 0.05 \)). There were also no significant differences between pre-intervention #1 and pre-intervention #2 gait parameters within each group for all neck conditions (all \( p > 0.05 \)).

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Treatment Group (n=20)</th>
<th>Sham Group (n=20)</th>
<th>Independent t-test p-value</th>
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<tr>
<td>Average Height (inches)</td>
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<td>65.8</td>
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</tr>
<tr>
<td>Average Weight (pounds)</td>
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<td>Gender</td>
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<td>M = 3, F = 17</td>
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<td>Duration of Symptoms (months)</td>
<td>45.7</td>
<td>23.6</td>
<td>0.09</td>
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Table 1
Subject Demographics and Independent t-test p-values

Gait Parameters

Univariate analyses were used with time and group as the independent variables, and each of the five gait parameters as the dependent variables. There were significant interactions found by 2x2 ANOVA between time and group on average gait velocity (\( p=0.008 \)), step length (\( p=<0.001 \)), and stride length (\( p=0.009 \)) when the head was in the neutral position.
Figure 7
The interaction between time and group for step length in neutral head position.
Figure 8
The interaction between time and group for stride length with head in neutral position.
Figure 9
The interaction between time and group for velocity with head in neutral position.

The TJM group experienced significant increases from pre-intervention #2 to post-intervention as shown by paired samples t-test for average gait velocity (p = 0.003), step length (p < 0.001), and stride length (p = 0.008) when the head was in the neutral position. The sham group however, experienced no significant change in gait velocity (p = 0.290), average step length (p = 0.299), and stride length (p = 0.292) when the head was in the neutral position. There were also no differences as shown by independent t-test between the two groups in mean step length, stride length, or gait velocity during the pre-intervention #2 and post-intervention trials (all p > 0.05). There were no other significant interactions or main effects as shown by 2x2 ANOVA of time or group on any of the five gait parameters in any of the three neck conditions (p > 0.05).
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<th>Pre-Intervention</th>
<th>Post-Intervention</th>
<th>P-value (paired samples t-test)</th>
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<td><strong>TJM</strong></td>
<td>59.538 cm</td>
<td>60.871 cm</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Sham</strong></td>
<td>63.295 cm</td>
<td>61.86 cm</td>
<td>0.299</td>
</tr>
<tr>
<td><strong>P-value (independent t-test)</strong></td>
<td>0.165</td>
<td>0.594</td>
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</table>

**Table 2**  
Step Length with Head in Neutral Position between the TJM and Sham Groups

<table>
<thead>
<tr>
<th></th>
<th>Pre-Intervention</th>
<th>Post-Intervention</th>
<th>P-value (paired samples t-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TJM</strong></td>
<td>119.294 cm</td>
<td>121.322 cm</td>
<td>0.008</td>
</tr>
<tr>
<td><strong>Sham</strong></td>
<td>124.807 cm</td>
<td>124.008 cm</td>
<td>0.292</td>
</tr>
<tr>
<td><strong>P-value (independent t-test)</strong></td>
<td>0.167</td>
<td>0.469</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3**  
Stride Length with Head in Neutral Position between the TJM and Sham Groups

<table>
<thead>
<tr>
<th></th>
<th>Pre-Intervention</th>
<th>Post-Intervention</th>
<th>P-value (paired samples t-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TJM</strong></td>
<td>107.431 cm/sec</td>
<td>110.362 cm/sec</td>
<td>0.003</td>
</tr>
<tr>
<td><strong>Sham</strong></td>
<td>116.149 cm/sec</td>
<td>114.704 cm/sec</td>
<td>0.290</td>
</tr>
<tr>
<td><strong>P-value (independent t-test)</strong></td>
<td>0.125</td>
<td>0.412</td>
<td></td>
</tr>
</tbody>
</table>

**Table 4**  
Velocity with Head in Neutral Position between TJM and Sham Groups
<table>
<thead>
<tr>
<th>Gait Measurement</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>P Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treatment</td>
<td>Sham</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sham</td>
<td>Treatment</td>
<td>Sham</td>
</tr>
<tr>
<td>Step Length (cm) Pre-intervention</td>
<td>59.538</td>
<td>62.295</td>
<td>5.519</td>
</tr>
<tr>
<td>Step Length (cm) Post-intervention</td>
<td>60.871</td>
<td>61.860</td>
<td>5.162</td>
</tr>
<tr>
<td>Stride Width (cm) Pre-intervention</td>
<td>9.542</td>
<td>8.480</td>
<td>2.370</td>
</tr>
<tr>
<td>Stride Width (cm) Post-intervention</td>
<td>9.062</td>
<td>8.483</td>
<td>2.371</td>
</tr>
<tr>
<td>Stride Length (cm) Pre-intervention</td>
<td>119.294</td>
<td>124.807</td>
<td>11.023</td>
</tr>
<tr>
<td>Stride Length (cm) Post-intervention</td>
<td>121.322</td>
<td>124.008</td>
<td>10.256</td>
</tr>
<tr>
<td>Velocity (cm/sec) Pre-intervention</td>
<td>107.431</td>
<td>116.149</td>
<td>14.545</td>
</tr>
<tr>
<td>Velocity (cm/sec) Post-intervention</td>
<td>110.362</td>
<td>114.704</td>
<td>14.036</td>
</tr>
<tr>
<td>Cadence (steps/min) Pre-intervention</td>
<td>107.666</td>
<td>110.933</td>
<td>7.177</td>
</tr>
<tr>
<td>Cadence (steps/min) Post-intervention</td>
<td>109.172</td>
<td>110.375</td>
<td>8.486</td>
</tr>
</tbody>
</table>

Table 5
Descriptive Statistics and ANOVA p-values with Head in Neutral Position
<table>
<thead>
<tr>
<th>Gait Measurement</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>P Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait Measurement Treatment</td>
<td>Sham</td>
<td>Treatment</td>
<td>Sham</td>
</tr>
<tr>
<td>Step Length (cm) pre-intervention</td>
<td>54.800</td>
<td>56.603</td>
<td>6.285</td>
</tr>
<tr>
<td>Step Length (cm) post-intervention</td>
<td>55.523</td>
<td>56.874</td>
<td>5.997</td>
</tr>
<tr>
<td>Stride Width (cm) pre-intervention</td>
<td>10.680</td>
<td>9.863</td>
<td>3.199</td>
</tr>
<tr>
<td>Stride Width (cm) post-intervention</td>
<td>10.782</td>
<td>9.102</td>
<td>3.133</td>
</tr>
<tr>
<td>Stride Length (cm) pre-intervention</td>
<td>109.604</td>
<td>113.276</td>
<td>12.643</td>
</tr>
<tr>
<td>Stride Length (cm) post-intervention</td>
<td>110.863</td>
<td>113.593</td>
<td>11.778</td>
</tr>
<tr>
<td>Velocity (cm/sec) pre-intervention</td>
<td>93.925</td>
<td>100.766</td>
<td>12.824</td>
</tr>
<tr>
<td>Velocity (cm/sec) post-intervention</td>
<td>95.198</td>
<td>101.549</td>
<td>14.305</td>
</tr>
<tr>
<td>Cadence (steps/min) pre-intervention</td>
<td>102.606</td>
<td>106.251</td>
<td>6.055</td>
</tr>
<tr>
<td>Cadence (steps/min) post-intervention</td>
<td>102.726</td>
<td>107.002</td>
<td>7.152</td>
</tr>
</tbody>
</table>

Table 6
Descriptive Statistics and ANOVA p-values for Neck Rotation Condition
<table>
<thead>
<tr>
<th>Gait Measurement</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>P Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treatment</td>
<td>Sham</td>
<td></td>
</tr>
<tr>
<td>Gait Measurement</td>
<td>Treatment</td>
<td>Sham</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-intervention</td>
<td>56.305</td>
<td>5.268</td>
</tr>
<tr>
<td></td>
<td>Post-intervention</td>
<td>56.749</td>
<td>5.596</td>
</tr>
<tr>
<td>Step Length (cm)</td>
<td>57.971</td>
<td>6.445</td>
<td></td>
</tr>
<tr>
<td>Stride Width (cm)</td>
<td>9.759</td>
<td>3.317</td>
<td></td>
</tr>
<tr>
<td>Stride Width (cm)</td>
<td>9.462</td>
<td>3.249</td>
<td></td>
</tr>
<tr>
<td>Stride Length (cm)</td>
<td>112.561</td>
<td>10.394</td>
<td></td>
</tr>
<tr>
<td>Stride Length (cm)</td>
<td>113.375</td>
<td>11.047</td>
<td></td>
</tr>
<tr>
<td>Velocity (cm/sec)</td>
<td>98.387</td>
<td>12.116</td>
<td></td>
</tr>
<tr>
<td>Velocity (cm/sec)</td>
<td>99.57</td>
<td>13.455</td>
<td></td>
</tr>
<tr>
<td>Cadence (steps/min)</td>
<td>104.537</td>
<td>6.078</td>
<td></td>
</tr>
<tr>
<td>Cadence (steps/min)</td>
<td>105.038</td>
<td>6.292</td>
<td></td>
</tr>
</tbody>
</table>

Table 7
Descriptive Statistics for Neck Flexion/Extension Condition
There was no statistically significant difference in gait parameters of individuals who had a positive compared to negative or absent GROC score, regardless of neck condition; step length (neutral $p = 0.49$, rotation $p = 0.44$, flexion $p = 0.67$), stride width (neutral $p = 0.48$, rotation $p = 0.27$, flexion $p = 0.62$), stride length (neutral $p = 0.45$, rotation $p = 0.45$, flexion $p = 0.68$), velocity (neutral $p = 0.45$, rotation $p = 0.35$, flexion $p = 0.55$), or cadence (neutral $p = 0.67$, rotation $p = 0.38$, flexion $p = 0.50$).

**Surveys**

There was no significant difference in NDI change scores between the groups ($p=0.169$), but a significant difference in NPRS change scores was found with an average decrease of 1.25 points in the TJM group ($p=0.003$). There was a statistical significant difference between the two groups on change in GROC score. The average TJM GROC score increased 2.85 while the sham group increased by 0.25 ($p=0.001$).
DISCUSSION

The significant interaction observed between treatment and time for velocity, step length, and stride length with the neck in neutral for the treatment group was unexpected in that there was not a similar significant interaction for any of the gait parameters during trials with neck rotation or flexion. Under the premise that an individual with mechanical neck ambulates with abnormal gait parameters as seen in Uthaikup et al, along with the presumption that the TJM would temporarily decrease mechanical neck pain as evidenced in Childs et al, gait parameters with dynamic neck movements were expected to improve to at least an equal degree of the improvements seen with the neck in neutral. While ambulating with neck rotation and flexion, subjects demonstrated decreased mean step length, stride length, gait velocity, and cadence and increased step width when compared to ambulation with neck in neutral. The absence of a significant interaction or main effect during ambulation with dynamic neck movements may be due to the possibility of the neck movements having a greater influence on an individual’s gait than the effect of receiving a TJM. This data reflects the statistics observed in Uthaikup et al in which gait parameters for participants with dynamic neck functions were consistently poorer (i.e. shorter gait step, shorter step length, slower velocity, slower cadence) compared to participants walking with a neutral neck.

There are number of factors to consider with these findings. First, the subjects in our study were asked to walk at a normal and comfortable speed. Multiple previous studies have analyzed gait with head movements using a metronome as an auditory cue in order to standardize head movements. The use of a metronome was not included into this study, as this could have
unintentionally promoted similar gait patterns in both groups by reducing the automaticity of gait.\textsuperscript{6,18} Similarly, during the trials with neck movements, the subjects were asked to rotate or flex their neck at a self-selected speed. The neck movements and walking speed were not standardized because the research design aimed to accommodate movements/speeds that were specific and functional for each subject. For example, one subject may self-select a speed of 1 rotation per second, which may not be comfortable for another subject who self-selects a speed of 1.5 rotations per second. Though the non-standardization of the speed of neck movements allowed for automaticity, it also created differences in the difficulty of dual-tasking while walking.

Since quality of gait was analyzed during head movements, there is a possibility of the subjects’ vestibular-ocular reflexes (VOR) affecting their performance. VOR are responsible for reflexive movement of the eyes in response to vestibular input to stabilize images on the retina in compensation of head and body movements. This reflexive component to gaze stabilization contributes sensory orientation information critical to postural stability and balance.\textsuperscript{25} If an underlying vestibular pathology was present, it may have created some degree of dizziness or unsteadiness during the neck movement conditions, which would influence balance and gait parameters.\textsuperscript{26} However, the demographics, past medical history, and lack of signs or symptoms of dizziness in the subject population allow researchers to assume that there were no significant pathological vestibular influences in data collection.

Neck pain, like all subjective symptoms, can arise from a myriad of etiologies. The subjects in our study reported neck pain for varying amounts of time. Our study did not investigate any
difference in TJM effect for acute vs. chronic neck pain which may have impacted our results. Although we ruled out trauma, ligamentous instability, ototoxic medicines or use of new medications, and surgical intervention, no further differential diagnosis was performed. One subject may have had a mild muscular strain from last month, while another may be suffering from a lifetime of fibromyalgia - very different conditions undergoing the same intervention. Future studies should attempt to isolate common diagnoses that report neck pain to see which respond most favorably to cervical TJM. This may involve extensive special testing and diagnostic imaging.

The relationship between the perceived amount of change in neck pain and disability following intervention and gait parameters was also investigated. There was no significant difference in gait parameters when comparing subjects with a positive GROC score to those with an absent/negative one. This contrasts with the Nystrom et al study which found that people who reported decreased levels of neck pain also ambulated with significantly increased velocity and step length. This may indicate that a positive change in neck condition perception is not sufficient on its own to improve gait parameters. Of the 21 subjects who had improved GROC scores, 7 reported only a small improvement in pain with GROC scores improving by only 1 or 2 points, which is less than the MCID of +3 points. It is possible that the change in perceived pain was not significant enough to directly affect gait parameters. However, this may be due to the fact that of the 21 subjects who had a positive GROC, only 14 of them met the MCID of +3. In summary, this means that whether or not a patient specifically reported improvement or non-improvement of symptoms had no correlation to changes in gait parameters.
While there was a statistically significant change in mean NPRS scores from pre-intervention to post-intervention between groups and a statistically significant difference between the mean GROC scores of the TJM and sham groups, these findings do not meet the threshold for minimal clinically important difference (MCID). One possible explanation for the failure of these results to meet the MCID threshold is the low levels of pain and disability that the subjects initially reported. The TJM group’s mean NPRS score of 3.15 decreased to 1.90 after receiving the TJM, which is a statistically significant decrease of 1.25. If the subjects had slightly higher levels of pain prior to receiving the TJM, the MCID of 1.3 for the NPRS may have been observed. The subjects’ GROC scores are also dependent on the initial NPRS scores because the GROC survey asks the subjects to rate the changes in condition of their necks from the time they presented to the time they finished participating. If the subjects perceived their neck conditions to be slightly worse prior to receiving the TJM, the TJM group’s mean GROC score of 2.85 may have been able to achieve the MCID of 3.

For cervical TJM to become more accessible to patients with chronic neck pain, its indications and effects need to become better understood. It is difficult to isolate functional changes attributable to TJM. Therefore, further research is warranted to better establish clinical practice guidelines on implementing TJM with appropriate patient populations.
LIMITATIONS

Although this was a double-blind randomized controlled study there were limitations that need to be addressed. First, subjects were instructed to walk at a comfortable, self-selected speed. This limited the ability of making valid comparisons between subjects, as walking at self-selected speeds can be influenced by many factors including environment, mental state, and perception of well-being. While the environment was controlled, the subjects could have walked at a non-typical rate since they were mindful that their gait was being recorded. In future studies, having a designated gait speed range for accepted data will allow for more accurate data analyses.

The verbal cues utilized during this study aimed to maximize cervical range of motion in trial conditions and sham active cervical rotation. The phrase “as far as you can” was part of the instruction for these head movements without any standard for the amount movement performed. It is also likely that the amount of cervical movement, which we did not measure, varied from subject to subject. Future studies may want to include head attachments or devices to better regulate and measure the amount of cervical movements performed.

One factor that may contribute to the limited findings of our study is the strength of the placebo effect for the sham intervention. The previous UNLV study used a hands-on sham treatment as a control. One of the discussed limitations to this method was the possibility that there was a placebo effect for the sham group.\textsuperscript{18} Our study utilized a hands-off active cervical rotation as the sham in an attempt to remove the possibility that the clinician’s touch evoked a symptom-reducing effect. However, the hands-off active rotation intervention as the sham may have decreased the desired placebo effect.
Subjects had varying intensities of pain ranging from mild to severe, and durations of symptoms ranging from one month to 17 years. The difference in severity and chronicity of symptoms may have limited the potential for improvement during the study. Future studies may include stricter inclusion criteria for severity or chronicity of symptoms to homogenize the population.

Despite the fact that subjects aged 18-70 were allowed to participate, the mean age of the subjects was 24.5 years old. The reason for this young subject population was because subjects were primarily recruited through UNLV e-newsletters and advertisements around the UNLV campus. As a result, these findings should not be generalized to populations other than college students from the Las Vegas area. Future studies could either focus on recruiting subjects from a more specific population or on recruiting subjects from a variety of sources in order to have a subject population that is more representative of the general population.

Of the outcome measurements utilized to record immediate changes after TJM or sham, the Neck Disability Index (NDI) may have been inappropriate due its inclusion of many different activities of daily living (ADL) that the subject found difficult to report on “immediately” without experience following the intervention. The NDI is an effective outcome measure to represent level of disability due to neck impairments, but when analyzing subjects within a single observation session, finding a change in disability scores seemed to be more based on subjects’ self-visualization of performing ADLs rather than actual physical performance of them. Therefore, future studies considering NDI and level of physical disability should have more prospective and long-term methodology to allow for subjects to experience the tasks included and report more accurately as they occur.
CONCLUSION
The results of this study suggest that the use of cervical TJM in individuals with mechanical neck pain may increase step length, stride length, and gait velocity when ambulating with a neutral neck position. Although statistical significance was achieved for these gait parameters, there are no clinical indications for cervical TJM to impact gait parameters in individuals with neck pain based on these findings. For example, our statistically significant increase in gait velocity with head in neutral of 0.03 m/s does not satisfy the threshold for a clinically indicated improvement in gait velocity of 0.13 m/s.\textsuperscript{27} Therefore, at this time there is no indication from this study that cervical TJM should be recommended to change gait parameters for patients that present with gait impairments and neck pain. Changes in subjective pain ratings offered statistical but not clinical significance as well. For instance, the GROC score improved by an average of 2.85 points, while MCID is validated at a minimum of a 3 point difference.\textsuperscript{22} Our findings cannot confirm clinical significance for reduction of neck pain with cervical TJM based on NDI, NPRS, or GROC questionnaires.

Although this study did not have clinically significant findings, the effectiveness of cervical TJM to improve gait and disability should continue to be explored. Future studies are warranted to build on the minor findings discussed and to discover other implications of using cervical TJM in clinical settings.
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- Puantedura, E, Albano, M, Blok, E, Gronert, B, Masuda, R. Immediate Effects of Cervical of Cervical Spine Thrust Joint Manipulations on Gait Parameters in Individuals with Neck Pain
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Continuing Education
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Research in Progress
- Puentedura E, Albano M, Blok E, Gronert B, Masuda R. Immediate effects of cervical spine thrust joint manipulation on gait parameters in individuals with neck pain.