Immediate Effects of Cervical Spine Manipulation on Gait Parameters in Individuals with and without Mechanical Neck Pain

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IMMEDIATE EFFECTS OF CERVICAL SPINE MANIPULATION ON GAIT PARAMETERS IN INDIVIDUALS WITH AND WITHOUT MECHANICAL NECK PAIN

By

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A doctoral project submitted in partial fulfillment of the requirements for the

Doctorate of Physical Therapy

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

University of Nevada, Las Vegas

May 2015
We recommend the doctoral project prepared under our supervision by

**Jordan Isom, Shaylyn Kennedy, Justin May, and Samuel Moore**

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**Immediate Effects of Cervical Spine Manipulation on Gait Parameters in Individuals with and without Mechanical Neck Pain**

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

**Doctor of Physical Therapy**

Department of Physical Therapy

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ABSTRACT

**Purpose:** The purpose of this study was to determine 1) if there were any differences in gait parameters between participants with mechanical neck pain and those without and 2) if cervical spine manipulation has an immediate effect on these gait parameters.

**Methods:** Twenty participants with mechanical neck pain and twenty participants without neck pain were randomly assigned into either the sham or manipulation group. The two intervention groups participated in walking across a GAITRite Walkway that recorded gait parameters such as stride length, cadence and step width before and after cervical spine manipulation. The participants walked at their own cadence with 1) head forward, 2) head turning up and down and 3) head turning side-to-side. T-tests were used to assess 8 different gait parameters between groups before and after intervention and to assess cervical range of motion differences between groups and before and after intervention in the sagittal, transverse and coronal plane. Repeated measures two-way ANOVA was used to assess pre and post intervention differences between groups in the NDI, NPRS and GROC. Post-hoc pair-wise corrections were to be used in the event of significant interactions between treatments and groups. Statistical significant was set at p <0.05.

**Results:** Compared to pain-free subjects, the T-tests demonstrated that patients with mechanical neck pain had smaller values of gait velocity, stride length, and step length before any treatment was provided (p<0.05). Prior to treatment, T-tests revealed no differences in cervical ROMs between persons with and without neck pain for the sagittal plane motion (P = 0.182); frontal plane motion (P = 0.347); and transverse plane (P = 0.181). The 2-way ANOVAs revealed a significant “group” main effect in gait velocity during normal walking (P=0.004), indicating participants with neck pain increased their
velocity whereas participants without neck pain demonstrated decreased velocity regardless of intervention given. A separate independent t-test indicated that there was a significant interaction in GROC score changes between treatment and group (P =0.043).

**Conclusion:*** Our study indicated that patients with neck pain walked more slowly with shorter stride length and step length. These gait characteristics observed might be strategies to compensate for gait instability, which involves proprioceptive deficits from the cervical spine. Additionally participants with neck pain increased their gait velocity post intervention whereas participants without neck pain demonstrated decreased velocity post intervention (manipulation/sham). While our results suggest TJM did improve gait velocity in those with neck pain post manipulation, we did not see significant changes in other gait parameters. This study suggests that clinicians should consider the assessment and management of gait performance, balance and risk of falling in patients with acute mechanical neck pain.
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>v</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>METHODS</td>
<td>8</td>
</tr>
<tr>
<td>RESULTS</td>
<td>17</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>20</td>
</tr>
<tr>
<td>LIMITATIONS</td>
<td>24</td>
</tr>
<tr>
<td>CONCLUSION</td>
<td>25</td>
</tr>
<tr>
<td>APPENDIX A – TABLES</td>
<td>26</td>
</tr>
<tr>
<td>APPENDIX B – FIGURES</td>
<td>28</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>37</td>
</tr>
<tr>
<td>VITAS</td>
<td>42</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1. Participant demographics 26

Table 2. Gait parameters (mean ± SD) under three different head movement conditions between control and neck pain groups 27
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Study design schematic</td>
<td>28</td>
</tr>
<tr>
<td>2</td>
<td>GAITRite mat rolled up and unrolled is a 14-foot carpeted mat</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>Unrolled GAITRite mat showing sensors and subject walking barefoot across mat</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>Cervical spine manipulation technique</td>
<td>31</td>
</tr>
<tr>
<td>5</td>
<td>Primary leverage of rotation with left hand, small secondary leverage side bending to opposite side with right hand. Finally, a rapid thrust in direction of arrow</td>
<td>32</td>
</tr>
<tr>
<td>6</td>
<td>Sham manipulation technique</td>
<td>33</td>
</tr>
<tr>
<td>7</td>
<td>Cervical range of motion in all planes between participants with neck pain and without neck pain</td>
<td>34</td>
</tr>
<tr>
<td>8</td>
<td>Change in gait velocity during normal walking for participants with and without neck pain by intervention provided</td>
<td>35</td>
</tr>
<tr>
<td>9</td>
<td>Global Rating of Change Scale (GROC) for all participants (with or without neck pain) following each intervention</td>
<td>36</td>
</tr>
</tbody>
</table>
INTRODUCTION

Mechanical neck pain is generally multifactorial in origin and refers to pain caused by placing abnormal stress and strain on joints, discs or muscles of the vertebral column. Typically, mechanical pain results from one or more of the following: poor posture, poor movement mechanics, anxiety, depression, neck strain, and sporting or occupational activities. The pain stays mainly in the neck and may be the result of intervertebral discs or facet (zygopohyseal) joints. This term is used because symptoms change with mechanical movement of the cervical spine.¹

The cervical spine is unique with an abundance of mechanoreceptors, muscle spindles and cervical afferents associated with the vestibular, visual and central nervous systems.² The cervical region plays an important role in supplying proprioceptive information to the postural control system.³ Dysfunction within components of the postural control system has been associated with an increase in postural sway and other measures of balance.³ Individuals with neck pain exhibit 130-170% greater postural sway during normal stance compared with asymptomatic controls.³

Research shows that in 2002-2004, the annual direct medical costs for all spine related conditions (cervical and low back) were estimated at approximately $194 billion. In addition, the estimated costs for indirect medical costs were $14 billion.⁴ Indirect costs may include work loss, worker replacement, and reduced productivity.

Poor postural performance has been observed in patients suffering from neck pain.³,⁵,⁶,¹⁴,¹⁵ The postural control for stability and orientation requires afferent input in
order to generate the appropriate torque in maintaining body position which may contribute to loss in balance.\textsuperscript{5} Dysfunction within components of the postural control system has been associated with an increase in postural sway and in energy expenditure required to maintain upright stance.\textsuperscript{6} Studies have shown that people with neck pain have a higher incidence of dizziness and falls resulting from poor sensorimotor function and balance.\textsuperscript{6,7,12,14,24,25}

Human balance is controlled via vestibular receptors located in the inner ears, via visual sensory systems, and via proprioceptive afferent systems that register the stretch and release of muscles acting across principle joints of the body and the angular motion of the joints.\textsuperscript{8} Neck pain may alter these sensory receptors innervating or surrounding cervical structures.\textsuperscript{9,10} The neck is particularly prone to this due to the abundant cervical sensory receptors in joints and muscles.\textsuperscript{9,10,11} The peripheral mechanoreceptors are the most important in joint stability, but in the cervical region they are also important for postural stability as well as head and eye movement control.\textsuperscript{10} A deficit in this afferent input could cause interactions within the three systems that control balance, thereby diminishing balance control and leading to an altering of gait characteristics.\textsuperscript{11} Patients with neck pain may exhibit greater postural instability than healthy controls demonstrated by greater center of pressure excursions. This may correlate with the extent of proprioceptive impairment secondary to pain.\textsuperscript{11} Conventional musculoskeletal intervention approaches may not have immediate effects for patients with neck pain and sensorimotor proprioceptive disturbances. More specific and novel treatment methods may be needed, such as manual therapy involving thrust joint manipulation (TJM).\textsuperscript{10}
Another point of interest is the important but less well researched reflexes involving postural control and orientation of the body, the vestibulocollic reflex (VCR) and the cervicocollic reflex (CCR). The VCR stabilizes the head relative to the trunk by activating neck muscles, and is mediated via the vestibular system. The CCR responds to stretch of the neck muscles and reduces the amplitude of head movement relative to the trunk. The control of posture and stability is dependent on the two systems integrating these signals to the central nervous system (CNS). The CNS transforms the signals into meaningful information about orientation. There is good evidence that the VCR and CCR are strongly influenced by neck proprioceptive information. As mentioned before, neck proprioception is influenced by pain, and this in turn may cause altered input to the CNS via these reflexes.

Puentejedura et al report that the majority of patients seen for neck pain will have had a major insult to the cervical spine such as a motor vehicle accident (MVA) or non-traditional mechanisms of jarring. Most patients who have had a whiplash injury experience sudden hyperextension followed by hyper flexion of the neck with no objective signs of damage to the cervical spine. Therapists are frequently frustrated by the poor results when treating patients with whiplash and 25% of patients involved in MVA’s will develop vestibular problems.

A study by Field et al found that neck pain groups were significantly less able to complete the eyes closed, tandem tests compared to control participants. Neck pain
groups had greater sway in stance tasks than controls and reduction in trunk sway for simple gait tasks such as walking while rotating the head. Another study by Grod et al, found statistically significant differences in judging vertical between symptomatic and asymptomatic participants.

Rix et al addresses the dense population of muscle spindles that is found in the small intrinsic muscles of the neck and the atrophy of these muscles has been linked to a loss of standing balance. They found it was reasonable to conclude that changes in head repositioning accuracy could result from structural pathology or alteration in the function of the spindle-rich muscles that may be due to muscle pain, ligamentous injury, articular pain or articular dysfunction. Rix et al tested cervicocephalic kinesthetic sensibility in patients with chronic neck pain of non traumatic origin. Because the head cannot move without movement in the cervical spine, and a subjective straight-ahead orientation is the reference point, this procedure also involves spatial and movement awareness of the head relative to the trunk. In this experiment, the participants were seated and blindfolded, and the trunk and limbs were kept stationary. This procedure potentially involves head-in-space information from the vestibular system and head-on-trunk proprioceptive information from the cervical spine mechanoreceptors.

A study by Treleaven, et al. found that unsteadiness is a common symptom reported by people who present with discreet but persistent whiplash-associated disorders (WAD) with no known vestibular pathology and these impairments were measured in tests of
sensorimotor control, namely cervical joint position error, the smooth pursuit neck torsion test and measures of postural stability.  

Physical therapy is the first management approach for many patients with insidious onset of mechanical neck pain, with manual therapy often being a preferred intervention.  

In fact, a common clinical approach for therapists is to incorporate manual therapy interventions directed to the cervical spine for the management of individuals with neck pain. These manual therapy techniques include passive non-thrust joint mobilization and TJM. High-velocity, low-amplitude spinal manipulation has long been used by manual therapists in the treatment of musculoskeletal complaints. Cervical spine manipulation to individuals with neck pain has been shown to reduce pain levels locally and in peripheral sites, increase force production by improving recruitment of inhibited musculature and improve kinesthetic performance. Acute alterations in cortical activity in regions related to sensory processing and sensorimotor integration changes up to thirty minutes after cervical spine manipulation in patients with neck pain. This may be due to improvements in neuromuscular performance after manipulation in patients with neck pain may result directly from the normalization of aberrant proprioceptive input associated with neck pain. A number of randomized controlled clinical trials support the application of cervical spine TJM in individuals with mechanical neck pain.

Two studies had similar results from identifying gait parameters with head movements in people with neck pain. A study by Poole et al investigated elderly patients with neck pain vs. no neck pain. The patients were to walk at a self-selected gait speed and turn
their head side-to-side. \(^{24}\) Another study by Uthaikhup et al also investigated gait parameters in participants with and without neck pain, but was inclusive to only participants with chronic neck pain. \(^{25}\) Uthaikhup looked at step width, step length, comfortable gait speed (self-selected) and max (fastest gait) speed. These participants also walked with head movements such as from side-to-side and up-and-down. Poole found that the elderly patients with neck pain demonstrated an increase in amplitude of sway (an indicator of reduced stability) during walking. The patients also revealed a slower self-selected gait speed while walking and turning their heads side-to-side, which implied apprehension. Uthaikhup found that the participants with neck pain had a narrower step width, shorter step length, slower gait speed, and slower max speed than their asymptomatic controls.

Our study will identify head movements with walking as these studies did but with patients who have acute neck pain (<6 months) rather than chronic pain. The majority of research into sensorimotor control disturbances has been undertaken in patients with persistent neck pain, however there is evidence that deficits could occur soon after the onset of pain. \(^{17}\) The two studies identify the difference in gait pattern between participants with and without neck pain but do not examine further treatment to identify any differences in gait made. We propose to continue the previous studies with the addition of cervical spine manipulation (versus a sham manipulation) as an intervention to identify the use of cervical spine manipulation as a treatment and compare gait parameters before and after treatment.
The primary purpose of this study is to determine whether there are any differences in gait variables between individuals with and without mechanical neck pain. The secondary purpose is to determine if cervical spine TJM has any immediate effect on gait parameters. The hypothesis of this study was that 1) persons with neck pain would have different gait parameters when compared to pain-free participants and 2) cervical spine TJM would have an immediate effect by improving gait characteristics of individuals with acute neck pain. The significance of the study will offer objective data to determine if TJM has any direct effects on gait characteristics such as velocity, cadence, step length, stride length and step width. If patients are unable to move their head while walking with distractions, then stability may decrease and risk of falling may increase. Findings from this study could help our understanding of how TJM works and also provide clinicians with useful information regarding gait characteristics and treatment of patients who have mechanical neck pain.

Participants with mechanical neck pain were recruited for this study. For the purpose of this study, mechanical neck pain was defined as generalized neck pain with mechanical characteristics including symptoms provoked by maintained neck posture or by movement, or by palpation of cervical muscles.
METHODS

Participants

The study consisted of 20 participants with mechanical neck pain and 20 age- and gender-matched controls without mechanical neck pain. Study participants were sought from the community, and were screened for eligibility to participate in the study. For participants with neck pain, the inclusion criteria included: 18-70 years of age, a minimum score of 10 out of 50 points on the neck disability index (NDI) (Table 1), and must have a complaint of mechanical neck pain with or without unilateral upper extremity symptoms. For the participants without neck pain, the inclusion criteria included: age and gender matched to the existing participants without neck pain. For both groups (with or without neck pain) exclusion criteria included ‘red flags’ noted in the participant’s Neck Medical Screening Questionnaire (i.e. tumor, fracture, metabolic diseases, rheumatoid arthritis, osteoporosis, severe atherosclerosis, prolonged history of steroid use, etc.); prior surgery to the neck or thoracic spine; any pending legal action regarding their neck pain; history of falls; and pregnancy. Additional exclusion criteria included: history of a whiplash injury within the past six weeks; diagnosis of cervical spinal stenosis or bilateral upper extremity symptoms; evidence of central nervous system involvement, including: hyperreflexia, sensory disturbances in the hand, intrinsic muscle wasting of the hands, unsteadiness during walking, nystagmus, loss of visual acuity, impaired sensation of the face, altered taste, and the presence of pathological reflexes (i.e. positive Hoffman's and/or Babinski reflexes). Lastly, participants could not have two or more positive neurologic signs consistent with nerve root compression, muscle weakness involving a major muscle group of the upper extremity, diminished upper extremity
muscle stretch reflex (biceps brachii, brachioradialis, triceps reflex), and diminished or absent sensation to pinprick in any upper extremity dermatome.

**Study Design**

This study was a prospective, double-blinded randomized and controlled study with an intervention group who received cervical spine TJM and a control group who received a sham intervention. Participants were put in two groups, those with mechanical neck pain and their age- and gender-matched controls without mechanical neck pain. These groups were randomly assigned into TJM and sham intervention groups (Figure 1). The study was conducted at the University of Nevada, Las Vegas (UNLV) Doctor of Physical Therapy Gait Analysis Lab. Pre- and Post- intervention data was collected using the GAITRite system. A complete description of data collection procedures has been included below. The Institutional Review Board (IRB) approval for the trial was given by the UNLV Office for the Protection of Research Subjects.

**Questionnaires**

**Numeric Pain Rating Scale** - An 11-point numeric pain rating scale (NPRS) was used to measure pain intensity. The scale is anchored on the left with a score of 0 and the phrase “no pain”, and on the right with 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 their least amount of pain in the preceding 24 hours. The average of the 3 ratings was used to represent the patient’s level of pain. The minimal detectable change (MDC) and minimally clinically important difference (MCID) for the NPRS have been reported as 2.1 and 1.3 points, respectively.²⁹,³⁰
Fear Avoidance Beliefs Questionnaire – The Fear-Avoidance Beliefs Questionnaire (FABQ) is a 16-item questionnaire designed to quantify fear and avoidance beliefs in patients with low back pain. The FABQ has 2 subscales: a 4-item scale to measure fear-avoidance beliefs about physical activity (FABQPA) and a 7-item scale to measure fear-avoidance beliefs about work (FABQW). Each item is scored from 0 to 6, with possible scores ranging from 0 to 24 for the FABQPA and from 0 to 42 for the FABQW and with higher scores representing increased fear-avoidance beliefs. As with previous studies, the FABQ was modified by replacing the word “back” with the word “neck”. Currently, there are few published estimates for the MDC and MCID for the FABQ also, an MDC of 12 points for the physical activity subscale (FABQ-PA) and 9 points for the work subscale (FABQ-W); however, these were for the Norwegian version.31,32

Neck Disability Index – The Neck Disability Index (NDI) is the most widely used condition-specific disability scale for patients with neck pain. The NDI consists of 10 items addressing different aspects of function, each scored from 0 to 5, with a maximum score of 50 points possible. The NDI has been reported to be a reliable and valid outcome measure for patients with neck pain. The MDC for the NDI is 5 points out of 50 whereas 7 points out of 50 was recommended for the MCID.33,34

Global Rating of Change – the 15-point Global Rating of Change (GROC) described by Jaeschke et al. The scale ranges from -7 (“a very great deal worse”) to 0 (“about the same”) to +7 (“a very great deal better”). It has been reported that scores of +4 and +5 are
indicative of moderate changes in patient-perceived status and that scores of +6 and +7 indicate large changes in patient status.\textsuperscript{24} Similar to the studies that developed and attempted to validate the CPR, 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) at any follow-up treatment session were considered to have experienced dramatic improvements. The MCID for the GROC has been reported as a 3-point change from baseline.\textsuperscript{28,35}

Participants with mechanical neck pain filled out the following questionnaires:

- Neck Medical Screening Questionnaire
- Demographic Information Sheet
- Informed Consent for Patient WITH Mechanical Neck Pain
- Body Diagram with NPRS
- FABQ
- NDI

Participants without mechanical neck pain did not need to fill out the NPRS, FABQ or NDI and therefore, only had to fill out the following:

- Medical Screening Questionnaire
- Demographic Information Sheet
- Informed Consent for Patient WITHOUT Mechanical Neck Pain

\textbf{Cervical Range of Motion Measurement}

Cervical range of motion was measured before gait analysis and immediately following the post gait analysis to determine any differences between the TJM and sham
intervention groups. Participants were asked to sit with good posture in a chair with back support and look forward. The device used to measure cervical flexion, cervical extension, right and left cervical rotation and right and left cervical lateral flexion was the cervical range of motion device (CROM). For all pre and post CROM measurements the participants were asked to move their head in a pain-free range of motion and a measurement was recorded. Then the patient was asked to move their head as far into that range as they can go and a measurement was recorded. The two values for each plane of movement were recorded and then averaged.

Instrumentation

Gait parameters were obtained with the GAITRite instrumentation (CIR Systems Inc. Sparta, NJ 07871) consisting of an electronic walkway 14 feet long and 3 feet in width (Figure 2). Pressure sensors are embedded in the mat in a horizontal grid. As the participant walked over the mat, the sensors closed under pressure, enabling collection of data on spatial and temporal gait parameters such as stride length, step length, base of support, velocity and cadence (Figure 3).

Procedures

The GAITRite mat was positioned in the lab to allow the participants to begin walking 3 feet before the mat, and to continue walking 3 feet past the end of the mat without slowing. By starting before the mat and continuing past its end, we assured that participants would be walking at their self-selected “steady” gait speed over the instrumented section of the mat. Participants were asked to walk across the GAITRite in socks or bare feet (participant preference) a total of 9 times for warm up, and to become
accustomed to the walking surface. Prior to data acquisition, they were asked to walk across 3 times at their normal walking pace; 3 times walking while looking up to the ceiling and down to the floor repetitively (cervical flexion/extension); and 3 times walking while looking to their left and to their right repetitively (cervical rotation). A metronome was set at 60 beats per minute during the second and third walking conditions (walking with head movements) to ensure all participants moved their head at the same frequency while continuing to walk at their preferred pace. After the 9 practice walks, participants were given a 5-minute rest period—sitting comfortably. Participants then walked across the GAITRite as before—3 times for each neck condition, and data was recorded during these walks.

Participants were then given one of 2 randomly assigned interventions to their cervical spine (neck)—either TJM or sham intervention, by the Principal Investigator (PI) who was blinded to gait and outcome measurements. The following is a detailed description of TJM applied to the right side of the cervical spine (Figure 4). The participant was supine with their neck in a neutral relaxed position on a pillow and the PI stood at the head of the treatment table and palpated the participant’s neck for any specific areas or segments of the neck that were tender or reproduced pain. The PI applied a contact point over the posterolateral aspect of the articular pillar of the particular cervical motion segment found to be tender or painful. The PI’s applicator was the lateral border of his proximal phalanx. Using a cradle hold, the participant’s head and neck was balanced between the PI’s left and right hand with cervical positioning controlled by converging pressure from both hands. The PI introduced primary leverage of rotation to one side and
small secondary leverage of side bending to the opposite side while maintaining contact on the posterolateral articular pillar. The thrust was achieved with a slight, rapid increase of rotation of the head and neck to the left with no increase of side bending to the right (Figure 5).

The Sham intervention technique consisted of a gentle (no motion) manual contact applied to the occiput and upper cervical spine. The participant lay supine with their neck in a neutral relaxed position on a pillow. The PI sat at the head of the treatment table and palpated the participant’s neck for any specific areas or segments of the neck that were tender or reproduced pain. The PI applied gentle contact with his hands under the base of the patient’s occiput and upper neck. No movement occurred. The gentle manual contact was be maintained for a total of 45 to 60 seconds, which was the same time that it would take to perform cervical spine TJM (Figure 6).

After the interventions were completed, the PI left the room and researchers who were blinded to the interventions returned to record the participants a second time as they walked across the GAITRite as before – 3 times for each neck condition. Data was recorded during these walks. After the second data collection session, the participants with neck pain filled out the following questionnaires:

- GROC
- NPRS
- FABQ
- NDI
Participants with no mechanical neck pain filled out the following questionnaire:

- GROC

**Data Analysis**

To determine if there were any differences in gait parameters between participants with neck pain and those without, we ran independent t-tests comparing eight different gait parameters: (1) velocity; (2) cadence; (3) step length left; (4) step length right; (5) stride length left; (6) stride length right; (7) step width left; and (8) step width right, under three walking conditions – (1) normal walking; (2) walking while moving the head and neck into flexion-extension; and (3) walking while moving the head and neck into rotation left and right. This analysis was conducted on the pre-intervention measures and was aimed at replicating the findings of Uthaikhup et al.22

To determine if there were any differences in cervical ROM between participants with neck pain and those without, we ran independent t-test comparing total sagittal plane ROM (Flexion ROM + Extension ROM), total frontal plane ROM (left lateral flexion + right lateral flexion), and total transverse plane ROM (left rotation + right rotation). We used the pre-intervention measures to compare between participants with and without neck pain.

To determine if intervention had any effect on gait parameters, we ran univariate analyses for each of the gait parameters that were found to be significantly different between participants with and without neck pain, for each of the 3 walking conditions. For these univariate analyses, the independent variables were presence of neck pain (yes/ no) and
type of intervention (sham/ manip) and change in gait parameter was the dependent variable.

To determine if intervention had any effect on patient reported outcome measures in the participants with neck pain, we ran repeated measures 2 (time: pre- and post-) by 2 (intervention: sham and manipulation) ANOVAs for NDI and NPRS. And finally, to determine if there was any difference in global perceived effect (GROC) for the interventions between participants with and without neck pain, we ran a separate ANOVA. All statistical analyses were conducted using SPSS v. 21 statistical package (International Business Machines Corp. New York, USA). All significance level were set at 0.05.
RESULTS

Pre-intervention gait parameters

The independent t-tests showed significant lower gait velocity in participants with neck pain for normal walking ($P = .003$); walking while moving the head and neck into flexion-extension ($P = .039$); and walking while moving the head and neck into rotation left and right ($P = .017$). (Table 2) These findings indicate that participants with neck pain demonstrated slower gait velocity than their healthy controls for all 3 walking conditions.

There were no significant differences in walking cadence between participants with and without neck pain for walking under any of the three conditions ($Ps > .05$). (Table 2)

Step lengths on the left and right were significantly shorter in participants with neck pain for each of the three walking conditions ($Ps \leq .009$). (Table 2) These findings indicate that participants with neck pain demonstrated shorter step lengths on both left and right sides when compared to their healthy controls for all 3 walking conditions.

Stride lengths on the left and right were significantly shorter in participants with neck pain for each of the three walking conditions ($Ps \leq .004$). (Table 2) These findings indicate that participants with neck pain demonstrated shorter stride lengths on both left and right sides when compared to their healthy controls for all 3 walking conditions.
Finally, there were no significant differences in step width on the left and right between participants for each of the three walking conditions \((Ps > .05)\). (Table 2)

**Pre-intervention cervical ROM**

The independent t-tests showed no significant differences in total cervical ROM in any plane; sagittal plane motion \((P = 0.182)\); frontal plane motion \((P = 0.347)\); transverse plane \((P = 0.181)\). These results indicate that while participants with neck pain appeared to have decreased mean total cervical ROM in all 3 planes, it was not statistically significant. (Figure 7)

**Effects of interventions on gait parameters**

We calculated change in gait parameters from pre- to post-intervention by subtracting the pre-intervention measure from the post-intervention measure. Therefore, any increases would be represented by a positive number and any decreases by a negative number. No change would equal to zero. As there were no significant differences between participants with and without neck pain for cadence, step width left and step width right. These 3 gait parameters were excluded from analysis. Fifteen separate univariate analyses (ANOVAs) with independent variables of presence of neck pain and intervention given were conducted for each of the following five dependent variables: (1) gait velocity; (2) step length left; (3) step length right; (4) stride length left; and (5) stride length right; each under the 3 different walking conditions.

There were no significant interactions for any of the 15 ANOVAs. Analysis of simple main effects revealed only one significant result. There was a statically significant
difference in the change in gait velocity during normal walking for participants with and without neck pain (P = 0.004), but not for intervention (P = 0.483). Participants with neck pain increased their velocity regardless of intervention given whereas participants without neck pain demonstrated decreased velocity regardless of intervention given. (Figure 8)

**Effects of interventions of patient reported outcome measures**

For the participants with neck pain, there were no significant main effects for NDI (P = 0.556) or NPRS (P = 0.870) following either intervention. With only 10 participants in each intervention group, observed power was low (5% and 8% respectively). There was a significant difference in GROC score changes between treatment and group (P = 0.043). Participants reported greater GROC scores following manipulation compared to the sham intervention. (Figure 9)
DISCUSSION

The results of this study demonstrate that there is a difference in certain gait parameters between participants with neck pain and those without. There were significant differences in gait velocity, left and right step length, and left and right stride length between participants with and without neck pain for the three walking conditions. These results are consistent with the findings of previous studies, which have demonstrated gait differences in participants with neck pain.\textsuperscript{7,13,23} It has been suggested that individuals with neck pain have gait disturbances due to abnormal information being sent to the cervical spine and influencing the integration of inputs to the sensorimotor control system.\textsuperscript{16} Furthermore these altered gait parameters may be a possible compensation for instability in those with neck pain which they have implemented when stability is challenged. Shorter step length and stride length decrease single limb stance time thus increasing stability and decreasing gait velocity.\textsuperscript{24}

There were no significant differences in step width on the left and right between participants for each of the three walking conditions. This was not consistent with the findings reported by Uthiakhup et al who noted that participants with neck pain had a narrower step width when compared to the control group while participating in dynamic gait activities involving head movements and speed.\textsuperscript{24} Their findings are not what we would have expected in individuals with neck pain. We would have expected an individual with neck pain to increase their base of support to enhance stability during dynamic activities. We must consider the difference between the studies. Uthiakhup et al examined individuals with chronic neck pain in contrast to our study which used acute...
(less than 6 months). It is plausible that over time, those with chronic neck pain will have adapted their base of support to resemble their original width characteristic.

No significant differences were found when comparing total range of motion between cervical pain and the control group. Although, subjects with neck pain appeared to have decreased mean total cervical range of motion in all 3 planes. Current literature demonstrates decreased range of motion is associated with cervical spine dysfunction and pain. It is plausible we could have found significance between groups by isolating range of motion measurements. Combining total range of motion in each plane could have masked significant differences between neck pain and control groups. For example, if subjects with acute pain have decreased range in one direction (e.g. flexion but also an increase in extension it would make the total range of motion the same.

The results of this study also demonstrated no statistically significant interaction in gait parameters after cervical spine manipulation. There are a number of factors to note that should be considered with respect to the study. First, the sample size in this study was small, and may not be representative of the general population of individuals with acute mechanical neck pain. The statistical power levels of the non-significant results were less than 0.8, indicating inadequate power to detect statistical significance (best was 0.3 but most analyses were less than 0.1). This may be explained by difficulties recruiting adequate number of participants with neck pain meeting inclusion and exclusion criteria. Strict criteria were used to control for any potential confounding factors in the analyses of outcomes. Nevertheless, adequate sample size was achieved to reproduce the study model
used by Uthaikhup et al. \textsuperscript{24} Secondly, our study investigated the immediate effects (within 60 seconds of intervention) of one spinal TJM on gait parameters. A study by Saavedera-Hernandez et al demonstrated patients who received multiple cervical manipulations exhibited greater effects than only one manipulation. \textsuperscript{18} Another factor to note when considering our study is that participants walked each condition at a self-selected pace (comfortable speed). Consequently, slow speeds may have compromised our ability to detect small differences in gait parameters. At a self-selected pace the dynamic activities may have been too easy. If participants walked at a higher speed their limits of stability may have been challenged enough to detect gait changes.

Participants with neck pain increased their velocity regardless of intervention given. This increased velocity may have resulted from a learned effect through multiple practice and pre intervention walking on the Gait Rite. It is likely that with each pass across the Gait Rite mat, participants became more comfortable with each walking condition, resulting in the increased gait velocity regardless of the intervention received. A solution for future similar studies would be randomizing the order of the walking conditions. We could argue that failure to randomize the order of the walking conditions would contribute to anticipatory learning effects that may minimize the likelihood of detecting any differences.

In theory, use of a metronome would have bolstered our study methods by standardizing the frequency of head movements. Using this instrument may have added another layer to the dual task making it difficult for some participants to walk at a pace independent of
the metronome tone. Some participants used the metronome tone to pace their
cadence of their gait, as well as, following it to standardize the frequency of head
turns. We found that the metronome use may have been a distraction for some which
may have influenced our results. Future studies should consider not using a metronome
rather have patients perform these motions at self-selected times to eliminate any
potential effects the external focus could have had on our results.

The results did not find significant differences for NDI or NPRS following either
intervention for participants with neck pain. This was not consistent with the study by
Saavedra-Hernandez et al, which showed participants who received manipulation
interventions exhibited decreased NDI scores. As reported earlier, the sample size in this
study was small with only 10 participants in each intervention group. Future larger
studies are required to provide adequate power to detect statistical significance. Our study
did however find significant interaction of higher GROC scores as a result of
manipulation intervention.
LIMITATIONS

Although employing this study to be a double-blinded randomized control study is a major strength of this study, the results should be interpreted with caution due to its limitations. Firstly, GaitRite mat sensors were not wide enough to accommodate the walking path for some participants. Therefore, some participant’s steps had to be deleted because the full step was not measured. Secondly, we must consider type II error when interpreting the results. The data reflects a small sample size causing the study to be underpowered. We consider any results with low power to be at risk for a type II error. Therefore, we could be reporting that there was no change in gait parameters post intervention when there actually was a change. Differences in gait may have been detected post intervention by challenging stability more through utilizing max walking versus self-selected speeds for each participant. Also, we recommend eliminating the use of a metronome, to minimize its possible influence on gait performance.
CONCLUSION

The results of the current study demonstrated that participants with mechanical neck pain walked more slowly with shorter stride length and step length. These gait characteristics observed might be strategies to compensate for gait instability, which involves proprioceptive deficits from the cervical spine. Additionally participants with neck pain increased their gait velocity post intervention whereas participants without neck pain demonstrated decreased velocity post intervention (manipulation/sham). While our results suggest TJM did improve gait velocity in those with neck pain post manipulation, we did not see significant changes in other gait parameters. We do not believe our research indicates TJM had no significant effect on the other gait characteristics, but rather indicates that any gait changes that may occur were undetectable due to limitations in our study.

In addition to our study, there is limited evidence on the specific effectiveness of cervical manipulation for improving gait. Future studies are needed and may be the way forward to determine if TJM would be a beneficial intervention in treating individuals with acute neck pain experiencing associated gait compensations or deficits.
APPENDIX A – TABLES

Table 1. Participant demographics.

<table>
<thead>
<tr>
<th></th>
<th>Controls (n = 20)</th>
<th>Neck pain (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female gender (%)</td>
<td>13 (65%)</td>
<td>13 (65%)</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>33.9 ± 12.7</td>
<td>34.6 ± 14.4</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>69.1 ± 12.3</td>
<td>69.7 ± 13.7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171.5 ± 11.3</td>
<td>167.4 ± 12.6</td>
</tr>
<tr>
<td>NDI (0-100)</td>
<td>-</td>
<td>20.4 ± 12.1</td>
</tr>
<tr>
<td>NPRS (0-10)</td>
<td>-</td>
<td>3.8 ± 1.7</td>
</tr>
<tr>
<td>FABQ</td>
<td>-</td>
<td>18.1 ± 12.6</td>
</tr>
</tbody>
</table>

Data are presented as mean ± sd unless otherwise indicated.

NDI = Neck Disability Index, NPRS = Numeric Pain Rating Scale, FABQ = Fear-Avoidance Beliefs Questionnaire (Neck).
Table 2. Gait parameters (mean ± SD) under three different head movement conditions between control and neck pain groups.

<table>
<thead>
<tr>
<th>Gait parameter</th>
<th>Side</th>
<th>Normal walking</th>
<th>Head flexion-extension</th>
<th>Head rotation left and right</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Controls</td>
<td>Neck pain</td>
<td>Controls</td>
</tr>
<tr>
<td>Velocity (cm/s)</td>
<td>N/A</td>
<td>129.3 ± 18.7</td>
<td>112.3 ± 14.2*</td>
<td>116.4 ± 24.9</td>
</tr>
<tr>
<td>Cadence (step/min)</td>
<td>N/A</td>
<td>113.5 ± 7.4</td>
<td>111.2 ± 8.3</td>
<td>109.0 ± 16.8</td>
</tr>
<tr>
<td>Step length (cm)</td>
<td>Left</td>
<td>67.9 ± 8.6</td>
<td>60.3 ± 7.0*</td>
<td>63.5 ± 9.1</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>68.7 ± 8.5</td>
<td>60.9 ± 6.3*</td>
<td>64.3 ± 8.1</td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>Left</td>
<td>136.7 ± 17.0</td>
<td>121.2 ± 13.0*</td>
<td>128.1 ± 17.1</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>136.8 ± 17.1</td>
<td>121.2 ± 13.1*</td>
<td>128.1 ± 16.9</td>
</tr>
<tr>
<td>Step width (cm)</td>
<td>Left</td>
<td>9.4 ± 1.9</td>
<td>9.2 ± 2.1</td>
<td>10.0 ± 2.2</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>9.6 ± 1.9</td>
<td>9.1 ± 2.1</td>
<td>10.2 ± 2.3</td>
</tr>
</tbody>
</table>

* Significantly different from controls ($P < .05$)
**Figure 1.** Study design schematic: NP = neck pain, CSM = cervical spine manipulation.
Figure 2. GAITRite mat rolled up (left) and unrolled (right) is a 14 foot carpeted mat.
Figure 3. Unrolled GAITRite mat showing the sensors and subject walking barefoot across the mat.
Figure 4. Cervical spine manipulation technique.
**Figure 5.** Primary leverage of rotation with left hand and small secondary leverage side bending to opposite side with right hand. Finally, a rapid thrust in direction of arrow.
Figure 6. Sham manipulation technique.
Figure 7. Cervical range of motion in all planes between participants with neck pain and without neck pain.
Figure 8. Change in gait velocity during normal walking for participants with and without neck pain by intervention provided.
Figure 9. Global Rating of Change Scale (GROC) for all participants (with or without neck pain) following each intervention – Manipulation and Sham Manipulation. Positive scores represent improvement compared to before intervention, and negative scores represent worsening.
REFERENCES


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Education
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• Combined Sections Meeting of the APTA, 2013 • San Diego, CA
• Explain the Pain Seminar by Dr. Adrian Lowe, 2012, 2013 • Las Vegas, NV

Research in Progress
• Puentedura E, Kennedy S, Isom J, May J, Moore S. Immediate effects of cervical
  spine manipulation on gait parameters in individuals with and without mechanical
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• American Physical Therapy Association (APTA) Student Member (2012-2015)
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  o American Heart Association

Continuing Education
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• “Early Mobilization in the ICU” by Shay Kennedy • 2014 • Murray, UT
• “Benign Paroxysmal Positional Vertigo” by Shay Kennedy • 2014 • Tooele, UT
• Combined Sections Meeting of the APTA, 2014 • Las Vegas, NV
• Combined Sections Meeting of the APTA, 2013 • San Diego, CA
• National Student Conclave of the APTA 2013 • Louisville, KY
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- St. Rose Dominican Hospital - Rose De Lima • Rehab • July 2014 – Sept 2014 • Henderson, NV
- Active Physical Therapy • Outpatient Orthopedic Clinic • July 2013 – August 2013 • Reno, NV

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- Pressure ulcers and the Braden scale (09/26/14)
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Research in Progress