The Concurrent Use of Intermittent Mechanical Cervical Traction and Neuromobilization Techniques in Patients with Cervical Radiculopathy

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Abstract

Background/Significance: Cervical radiculopathy (CR) is a common neck disorder involving injury to nerve roots which can lead to significant pain and disability. There is not consensus on the most effective strategy to treat CR. A recent physical therapy intervention using a concurrent treatment of intermittent cervical traction (ICT) and upper extremity neuromobilization techniques (NMTs) shows promise. However, this concurrent approach has not been compared to the standard multimodal approach using sequential ICT and upper extremity NMTs. **Purpose:** The purpose of the study was to determine if patients receiving the concurrent approach had differences in disability, neck pain, range of motion and treatment time compared to the sequential approach. **Methods:** Patients were randomized into either the concurrent ICT and NMTs or sequential ICT and NMTs treatment group. Patients were followed for up to four weeks. Pre-intervention and post-intervention measures for neck disability index, cervical range of motion (ROM), and the numeric pain rating scale were collected and analyzed for within and between group differences. Treatment time for each visit was compared between the concurrent and sequential groups. **Results:** There were significant differences in neck disability, cervical ROM, and pain within both groups from pre-intervention to post-intervention; however, no significant differences were found between the concurrent and sequential groups. The concurrent approach had a significant decrease in treatment time per visit compared to the sequential group. **Conclusion:** The concurrent approach was effective in reducing pain and improving function for patients with cervical radiculopathy. In addition, the concurrent approach used less time per session.

Keywords: Cervical radiculopathy, neck pain, intermittent cervical traction, neuromobilization techniques

The Concurrent Use of Intermittent Mechanical Cervical Traction and Neuromobilization Techniques in Patients with Cervical Radiculopathy

Cervical radiculopathy (CR) is a nerve root disorder typically caused by cervical disc herniation, spondylitic spur, or other space occupying lesion that can impinge or inflame the accompanying nerve root (Cleland, Whitman, Fritz, & Palmer, 2005). Most CR occurs unilaterally; however, bilateral symptoms can occur in rare instances (Eubanks, 2010). Common signs and symptoms are neck pain that radiates into the arm coupled with motor, sensory, and/or reflex changes (Rao, 2002).

To date, the optimal treatment for CR remains unclear. Although surgical interventions continue to have a high incidence in its treatment (Marquez-Lara, Nandyala, Fineberg, & Singh, 2014; Oglesby, Fineberg, Patel, Pelton, & Singh, 2013), they have not been shown to be more effective than conservative management such as physical therapy in reducing pain or improving function (Engquist et al., 2013). Within the available physical therapy literature, there is no general agreement on how to best manage patients with CR. Current best evidence suggests that a multimodal treatment program consisting of exercise, manual therapy techniques including neuromobilizations, followed by mechanical traction may best reduce pain and improve function in patients with CR compared to the use of only one treatment type (Boyles, Toy, Mellon, Hayes, & Hammer, 2011; Cleland et al., 2005). Other studies demonstrated effectiveness when using cervical lateral glides with neuromobilizations, without mechanical traction (Coppieters, Stappaerts, Wouters, & Janssens, 2003, Rodríguez-Sanz et al., 2017). Despite evidence suggesting multimodal treatment to be effective in treating patients with CR, a standardized multimodal treatment protocol has not been established. A recent study involved the concurrent administration of manual cervical traction and upper extremity neuromobilizations in which

patients demonstrated improved range of motion and function compared to a control group (Savva Giakas, Efstathiou, Karagiannis, & Mamais, 2016). In addition, another study involved a concurrent approach with mechanical cervical traction and neuromobilizations and had good outcomes with regards to pain and function (Kumar, Kumar. Arjunan, & Thoufiq, 2017). These studies show promise in a concurrent approach to the treatment of patients with CR. However, in both studies the interventions were not used in conjunction with a multimodal approach. Additionally, it would be important to know if using mechanical cervical traction in a concurrent approach would benefit the patient and therapist with regards to a saving in time.

Therefore, the current study looked at the use of concurrent mechanical traction and upper extremity neuromobilization techniques along with exercise and manual therapy in patients with CR compared to a treatment approach of exercise, manual therapy and sequential mechanical traction and upper extremity neuromobilization techniques. Both treatment protocols used for this study are expected to be effective in the treatment of CR and should improve patient function and pain. The benefits the concurrent approach may have over the sequential approach is that it may improve neural mobility under the force of traction and it may reduce treatment time for the patient and the therapist. The purpose of the study is to determine if a multimodal treatment protocol that includes mechanical traction concurrent with neuromobilization techniques offers any benefit over sequential mechanical traction and neuromobilzation techniques in treating patients with CR. To address this purpose, the following null hypotheses were tested:

1. There will not be a statistically significant difference in pain, measured by the numerical rating of pain score (NPRS), at the end of treatment between participants who receive the concurrent approach when compared to participants who receive the sequential approach.

2. There will not be a statistically significant difference in functional outcomes, measured by the Neck Disability Index (NDI), and cervical range of motion (ROM) at the end of treatment between the concurrent approach and the sequential approach.
3. There will not be a statistically significant difference in mean treatment time measured in minutes for patients receiving the concurrent approach compared to participants who receive the sequential approach.

This study should add to the knowledge base of how patients with CR are treated conservatively. No study to date has compared a sequential multimodal approach of treatment to a concurrent multimodal approach. If found to be more effective, the sequential approach may improve outcomes in this patient population. If less treatment time is required, therapist productivity may improve and the cost of care may decrease.

Literature Review

Cervical radiculopathy is one of the main reasons for neck pain (Goode, Freburger, & Carey, 2010). Neck pain has a prevalence of 34% in the general population (Bovim, Schrader & Sand, 1994). It is most prevalent in females and in the fourth and fifth decades of life (Goode, Freburger, & Carey, 2010; van Hulst,van Oostrom, Ostelo, Verschuren, & Picavet, 2016). It is estimated that 14% of the general population will have their first episode of neck pain in any given year (Cote, Cassidy, Carroll, & Kristman, 2004). For those with a new onset of neck pain, 14% (Bovim, Shcrader & Sand, 1994) to 24% (Cote et al., 2004) reported recurrent or persistent neck pain lasting greater than 6 months. The prevalence of CR has been estimated at 83 cases per 100000 persons (Radhakrishnan, 1999).

Defining Cervical Radiculopathy

Classic symptoms of CR include one or all of the following: neck and or shoulder pain, diminished muscle stretch reflexes, sensory loss and/or motor loss (Cleland et al., 2005; Radhakrishnan, 1999; Wainner, 2000,). Electrodiagnostic studies, namely needle electromyography (EMG) are often used in diagnosing or ruling out radiculopathies (Dillingham et al., 2001, Hakimi & Spanier, 2013). Sensitivity values range between 50-71% (Hakimi and Spanier, 2013), to nearly 98% (Dillingham et al., 2001) depending upon the number of muscles assessed. Specificity of EMG for diagnosis of radiculopathy has been recorded at 77% (Narayanaswami et al., 2016).

Needle EMG has been shown to be most sensitive when symptoms were less than three months from onset (Partanen, Partanen, Oikarinen, Niemitukia, & Hernesniemi, 1991). Since Needle EMG only detects motor changes in the axonal portion of the nerve, it has not been found to be beneficial in detecting radiculopathies with a sensory component or radiculopathies from demyelination (Hakims & Spainer, 2013). In a clinical review, Kuijper et al. (2009) recommended needle EMG for ruling out radiculopathy, but could not recommend it for diagnostic value. In their review, spiral CT was considered a better option for diagnosing CR from a degenerative standpoint whereas magnetic resonance imaging (MRI) was useful in detecting disc protrusions. However, diagnostic accuracy is not known on these two imaging techniques for patients with CR (Kuijper et al., 2009). Based on the available literature, diagnostic tests can be useful screening tools but should be used in conjunction with patient interview and physical examination.

The clinical diagnosis of CR has been challenging due to low diagnostic accuracy of clinical tests (Rubinstein, 2007), and only a weak relationship between imaging findings and symptoms (Lee, 2013) In a review, Wainner and Gill (2000) discussed the lack of an agreed

upon criteria to diagnose CR and although specific provocative tests have been advocated, there were few prospective studies on the efficacy of such tests. However, attempts have been made to increase the likelihood of diagnosing CR (Wainner & Gill, 2000). Wainner et al. (2003), conducted a prospective diagnostic test study on 82 patients thought to have CR or carpal tunnel syndrome based on EMG and nerve conduction studies (NCS). Patients completed a subjective history, rated their pain on a visual analog scale (VAS) and completed the neck disability index (NDI). Patients then underwent a 34 item standardized clinical examination including cervical range of motion (ROM), neurological testing and provocative special tests. Initially, eleven variables were found to have acceptable diagnostic accuracy and were entered into a regression model. Upon analysis, the authors found the best test item cluster for a diagnosis of CR was; 1) positive upper limb tension test A (ULTT A), 2) cervical rotation less than 60 degrees to the involved side, 3) positive neck distraction test, and 4) positive Spurling A test. If all four variables were present, the specificity of diagnosis was 99% with a positive likelihood ratio (+LR) estimate of 30.3. And, when three of four variables were present, the specificity of diagnosis was 94% with a +LR of 6. Of the four tests, the ULTT was the most sensitive and therefore beneficial to rule out CR while Spurling A was the most specific and therefore, beneficial for ruling in CR (Wainner et al., 2003). More recently, Ghasemi et al. (2013) assessed the clinical utility of three tests in defining CR; shoulder abduction test (SAT), Spurling test (ST) and the upper limb tension test (ULTT). Clinicians performed the three tests on 100 patients and then using electrodiagnostic test results, determined if they had CR. Further separation was performed in determining if the patient had acute or chronic CR. Diagnosis of acute or chronic was based on electrodiagnostic tests versus time from onset. Sensitivity, specificity, and positive and negative predictive values were calculated. The SAT and ST were found to be highly

specific (85%) for both acute and chronic CR, making them appropriate tools to rule in the diagnosis of CR, while the ULTT was found to be most sensitive (65%) for acute CR and appropriate to rule out a diagnosis of CR. However, for sensitivity, no test in this study was found to be of significant value for those patients diagnosed with chronic CR (Ghasemi et al., 2013).

Diagnosing between cervical and shoulder dysfunctions can be difficult as arm pain is common in both conditions. Spurling's test exhibits moderate specificity which can rule in CR (Tong, Haig, & Yamakawa, 2002, Wainner et al., 2003). Another test that is used to differentiate shoulder and neck symptoms is the Arm Squeeze Test. It involves squeezing the upper third of the involved arm with moderate force. Complaints of local pain is considered a positive test for cervicobrachial symptoms. It is hypothesized that this area of the upper arm includes the musculocutaneous, radial and ulnar nerves. It has been found to have high sensitivity and specificity (Gumina, Carbone, Albino, Gurzi & Postacchini, 2013). In review of the studies above, no single gold standard test has been established to effectively diagnosis CR. A combination of clinical examination that correlates with EMG or imaging study findings appears to be most beneficial.

Mechanical Traction

Mechanical traction is thought to have many physiological effects including increasing diameter of neuroforaminal openings, reducing disc protrusions, stretching of spinal and ligamentous structures, and straightening of spinal curves. Other benefits include muscle inhibition, muscle relaxation and pain reduction (Bellew, 2016). Mechanical traction forces can be applied via intermittent or continuous settings. Graham, Gross, Goldsmith, and the Cervical Overview group (2006) conducted a systematic review, which investigated the effectiveness of

types of traction on pain, disability and patient satisfaction. The pool of patients included mechanical neck pain, neck pain with headache, and neck pain with arm pain. Of the studies reviewed, the authors concluded most had design flaws and the evidence overall was inconclusive. However, based on the results of the studies, for clinical consideration, intermittent cervical traction (ICT) was more effective than continuous traction in the treatment of patients with neck disorders (Graham et al., 2006). A recent meta-analysis showed support for both manual and mechanical traction for short and intermediate effects on patients' pain (Romeo et al., 2018). However, in a previous study, patients treated with mechanical traction had better outcomes with regards to pain and function when compared to manual traction (Bukhari, Rehamn, Ahmad, & Naeem, 2016).

It would be beneficial to be able to identify a sub group of patients with neck pain who would respond to ICT. This would have the potential to improve outcomes by matching patients to interventions and furthermore, would demonstrate the effectiveness of ICT. Raney et al. (2009) developed a clinical prediction rule (CPR) to identify patients with neck pain who would benefit from ICT and exercise. After a standardized battery of tests, 68 patients with neck pain, with or without arm symptoms, were treated with ICT and an exercise program. Using logistic regression analysis, five variables were used in the final analysis: 1) age > 55, 2) patient reported peripheralization of symptoms with lower cervical (C4-C7) mobility testing, 3) positive shoulder abduction test, 4) positive neck distraction test, and 5) positive ULTT A. If 4 out of 5 variables were present, the +LR was 23. If 3 of 5 variables were present, the +LR was 4.8 (Raney et al., 2009). This study had similarities to the Wainner et al. (2003) study looking at defining CR. Two tests, neck distraction and ULTT A were found in each study and the positive shoulder abduction test was found to have high specificity (92%) in Wainner et al. (2003), although it did not make

the final analysis. It seems apparent that patients with CR, could be part of the sub group that would benefit from ICT.

Effectiveness of Intermittent Cervical Traction

In a case series by Moeti and Marchetti (2001), 15 patients with cervical radiculopathy were treated using ICT. Based on patient presentation some patients also received mobilization or manipulation to the cervical spine and all patients completed some form of exercise. The majority of patients reported decreased pain and disability. Patients with symptoms less than 12 weeks had even better outcomes (Moeti & Marchetti, 2001). More recently, 27 patients with CR were randomly assigned to one of two groups; exercise only or exercise with ICT mechanical traction. After 15 treatment sessions over a three-week period, the exercise and ICT demonstrated increased grip strength and decreased pain (Aydin & Yazicioglu, 2012). Bukhari et al. (2016), randomly assigned 42 patients (36 would complete the study) with cervical radiculopathy to either receive ICT or manual traction along with segmental mobilization and exercise. Each group had 18 treatment sessions. Both groups had statistically significant improvements in pain and disability, but the ICT group's numbers were found to be more clinically meaningful (Bukhari et al., 2016). In the study by Aydin and Yazicioglu (2012), follow- up was limited. These short-term results favor ICT, but a longer follow up would be more beneficial to determine duration of improvement. Fritz et al. (2014), looked at two different types of traction compared to an exercise only group. Eighty-six patients were randomly assigned to one of three groups; exercise only, exercise and over the door traction, and exercise and supine ICT. Follow up assessments were performed at 4 weeks, 6 months and 12 months after onset of the study. Both traction groups had better results on pain and disability than the exercise only group. Findings were most significant at six months. The authors also noted the

mechanical traction group performed in supine was superior to the over the door traction device (Fritz et al., 2014). Jellad et al. (2009) randomly assigned 39 patients into one of three groups: manual traction and standard rehabilitation, ICT and standard rehabilitation and standard rehabilitation alone. Follow-up included a 6-month assessment. Both groups of traction had decreased neck and arm pain and improved function lasting to the 6 month follow up (Jellad et al., 2009). Finally, Moustafa and Diab, (2014) performed a randomized controlled trial to examine the effectiveness of two ICT positions on patients with chronic (> 3 months duration) CR. Patients with positive findings for a C6-C7 radiculopathy were randomly assigned to one of three groups; a multimodal treatment of exercise, modalities, soft tissue and thoracic manipulation only, ICT in 24 degrees of ventroflexion and the multimodal treatment and ICT in 5 degrees of extension and the multimodal treatment. Patients were seen three times a week for four weeks and were followed for up to one year. Pain and disability were assessed using the VAS and NDI respectively. Results significantly favored the ICT in 5 degrees of extension and was still present at the one-year follow up. The ventroflexion group had improved significantly after the four-week intervention but results were not significant and were similar to the multimodal alone group at 1 year (Moustafa & Diab, 2014).

It appears that ICT has a favorable impact on patients with CR. However, the heterogeneity of study designs reviewed impact the ability to draw conclusions or make a consensus on recommending the intervention. A Cochrane review by Graham et al. (2011) could not find evidence to support or refute the use of mechanical traction for neck pain. However, Vetroczky and Lauber (2017), in their critically appraised topic (CAT), found evidence to support the use of intermittent mechanical traction when used in a multimodal treatment approach. In addition, a case series by Cleland et al. (2005) found 10 of 11 patients treated with a

multimodal approach of manual therapy, exercise and ICT had improved pain and function at discharge and 6-month follow-up. Although a cause and effect relationship could not be inferred with a case series, it provided support for the approach (Cleland et al., 2005).

There was heterogeneity in the studies reviewed. Studies varied on the amount of time on traction. For instance, in Jellad et al. (2009), patients had ICT for two 25 minute sessions with a 10-minute rest period. Patients in the study by Fritz et al. (2014) and Moustafa and Diab (2014) had one session for 15 minutes and one session for 20 minutes respectively. Additionally, studies also varied with regards to the device used, angle of pull, and the additional treatment interventions performed (Fritz et al., 2014; Jellad et al., 2009; Moustafa & Diab., 2014). Overall, based on the studies reviewed, ICT in the supine position in either ventroflexion or 5 degrees of extension, used in conjunction with a multimodal treatment regimen was found to be effective in reducing pain and disability in patients with acute (less than 3 months' duration) CR.

Neuromobilization Techniques

In its healthy state, nerve tissue adapts to mechanical stress including tension, compression and elongation. With injury, such as CR, adverse effects such as neural edema, hypoxia, and fibrosis may occur (Butler 2000). The primary goal of neuromobilization techniques (NMTs) is to restore the normal mechanics between the injured nerve and surrounding tissue thus reducing edema, increasing nerve gliding, and reducing nerve adherence. There are three main types of NMTs; tensioning techniques, sliding techniques and lateral glides (Efstathiou, Stefanakis, Savva, & Giakas, 2015). Tensioning techniques use a combination of movements at multiple joints to elicit nerve lengthening via lengthening of the nerve bed. The nerve bed is made up of the surrounding tissues that provide the surface area where the nerve moves. The overall effect is one of nerve lengthening. However, increased pressure and strain on

the nerve has been demonstrated with tensioning techniques (Coppieters & Butler, 2006). In contrast, sliding techniques involve a combination of movements thought to elongate a nerve at one joint while simultaneously shortening it at an adjacent joint. The benefit of the sliding technique is the avoidance of increasing neural pressure and strain while producing excursion of the nerve (Coppieters & Butler, 2008; Dilley et al., 2005). In addition to sliders and tensioners, lateral glides are techniques that produce movement at the intervertebral foramen thought to reduce mechanosensitivity of the associated nerve root (Coppieters et al., 2003; Rodriquesz-Sanz et al., 2017).

Effectiveness of Neuromobilizations Techniques

Nar (2014) compared the use of NMTs and conservative treatment to only conservative treatment. Fifteen patients were assigned to each group and received electrical stimulation, ICT, isometric exercise and education. The experimental group also received NMT in the form of ULTT1 or otherwise called, ULTT A. This procedure places the involved limb in scapular depression, shoulder abduction and lateral rotation, elbow supination, and wrist and finger extension. For this study, once a barrier was appreciated, the clinician provided movement at the wrist component into the barrier making this a tensioning technique. Initial treatment was for a few seconds in duration and worked up to 20-30 seconds with adjustments to the amplitude of wrist movement and duration of oscillations. Results showed significant reduction in pain in both groups. A significant difference was also found between groups; the experimental group was more effective at reducing pain. Although not formally discussed, the follow up was only short term (Nar, 2014). Ragonese (2009), randomly assigned 30 patients with neck and arm pain into one of three groups; manual therapy only, exercise only, and manual therapy and exercise. Manual interventions included lateral glides, sliding techniques and tensioning techniques.

Significant differences were found between treatment groups for a reduction in pain and improved scores on the NDI. The combination group exhibited the greatest improvement. For treatment using neural glides, the author used a sliding technique initially and then changed to a tensioning technique once symptoms had improved (Ragonese, 2009). Nee et al. (2012) randomly assigned patients with neck pain into one of two groups. One group received NMTs along with manual therapy and education while a control group was advised to continue their daily activities. Patients were treated for two weeks. Improvements were noted in pain scores and NDI scores in the treatment group (Nee et al., 2012). Allison and Hall (2002) randomly assigned 30 patients with cervicobrachial pain to one of three groups; NMTs that comprised of lateral glides and scapular oscillations, articular techniques aimed at shoulder and thoracic spine mobilizations, and a control group. The control group did not receive treatment for the duration of the study. Patients were treated for 8 weeks. Both manual therapy groups had significant improvements in pain and disability while the NMT group was found to be more significant at the 8-week assessment. However, the authors noted the difference between groups was statistically significant but not necessarily clinically significant (Allison & Hall, 2002). Efstathiou et al. (2015) performed a critical review on NMTs for spinal radiculopathy. Specific to CR, the authors review demonstrated positive findings from NMTs. However, due to the heterogeneity between studies, the results remained inconclusive (Efstathiou et al., 2014). Basson et al. (2017) performed a systematic review on the effectiveness of NMTs for a variety of neuromusculoskeltal conditions. For subjects with nerve related neck pain, they found that NMTs had a positive effect on pain and disability. However, the authors noted that the studies measurement techniques were not consistent and some studies did not list the specific interventions such as, slider, tensioner or lateral glide techniques (Basson et al., 2017).

The review for NMTs effectiveness is similar to the ICT review. Study heterogeneity impacted the ability to make specific statements on the effectiveness of the treatments. However, both interventions had a positive impact on the outcome of patients with CR.

Concurrent Use of Intermittent Cervical Traction and Neuromobilization Techniques.

Few studies reviewed looked at the concurrent use of traction and NMTs. In a case report, Savva and Giakis (2013) used intermittent manual traction simultaneously with a sliding technique. The patient presented with a 2-month history of neck and arm pain. The patient had positive neurological findings of impaired sensation and motor weakness. In addition, the patient tested positive on all four tests of the clinical prediction rule for patients with CR as described by Wainner et al., (2003). Treatment consisted of manual cervical traction with the head in neutral while the patient received a sliding technique administered by a second clinician. Six sets of 1-minute duration interventions were performed at each session. The patient was seen for 12 visits over a four-week period. At the end of the twelfth visit, the patient had almost a complete reduction in pain and was completing household activities without symptoms. Improvements were also noted on NDI scores (Savva & Giakis, 2013). Although case studies cannot be used to infer cause and effect, this study presented an alternative treatment to patients with CR. Savva et al. (2016) followed this case study with a randomized control study. Forty-two patients diagnosed with CR were randomly assigned to either receive manual traction and NMTs or serve as a control. The control group was asked to avoid treatment and to stay active. As in the previous case study, patients were treated for 12 visits using a sliding technique during manual intermittent traction. Outcomes were assessed at baseline and at the end of the four weeks of treatment. The experimental group demonstrated significant improvements in pain, grip strength, function and cervical ROM. This study demonstrated the concurrent use of traction and NMTs to

be effective. However, follow up was limited to the time of intervention making long-term benefits of the treatment uncertain (Savva et al., 2016). Kim, Chung, and Jung (2017) randomized 30 patients; 15 received NMTs concurrent with manual traction and 15 received only manual traction. Those patients who received the concurrent approach had significantly better results on pain, disability, range of motion (ROM) and deep neck flexor strength when compared to the manual traction group (Kim et al., 2017).

Recently, one study compared the concurrent approach of mechanical ICT with NMTs to a group who received NMTs and a group that received ICT (Kumar et al., 2017). This was the first study noted that used mechanical traction concurrently with NMTs. Twenty patients were randomized into each group and were followed for four weeks with a total of 12 treatment interventions. At the end of four weeks, the concurrent approach group had significant improvements in pain and disability when compared to the other two groups. The inclusion criteria was limited with regards to age range (45-55 years) and based on statistical analysis, it does not appear that the concurrent approach had a better outcome compared to the NMTs group, $p = .097$, 95% CI [-8.35, 0.55] (Kumar et al., 2017).

To date, no study has looked at using the concurrent approach of ICT with NMTs to the sequential approach of ICT and NMTs. In addition, no study has looked at the inclusion of exercise into each group. In a clinical setting, patients routinely are treated with multiple approaches and it would be of benefit to know if the concurrent approach would be more effective. With this approach, the patient may experience reduced pain during the intervention, which could improve satisfaction and possibly compliance with the treatment program. In addition, the use of mechanical traction with NMTs could be performed with one clinician and reduce patient treatment time making it more efficient.

Treatment Time

In a fee for service model and escalating health care costs, the need to maximize therapist productivity and efficiency is paramount (Johnson et al., 2017). Krebs, Volpe, Aisen, and Hogan (2000) discussed three ways to improve productivity while not negatively impacting quality of care; 1) develop and practice evidence based therapy, 2) lessen the burden of non-clinical practices and 3) improve the productivity of individual clinicians. The concurrent use of ICT and NMTs could provide improved productivity in each of the three ways. Evidence does support the use of a multimodal approach, which includes ICT and NMT. In Savva et al. (2016), two clinicians were used to perform the treatment of manual traction and NMTs. Using one versus two clinicians during a treatment session would allow the second clinician time to treat other clients which in theory lessens the burden and allows more clients to be seen during a given period of time. Kumar et al. (2017) was able to demonstrate that the concurrent approach was effective. However, it was not included into a multimodal approach and treatment time was not discussed (Kumaar et al., 2017). When compared to other multimodal approaches, the concurrent approach may lessen the amount of time the client is being treated. If used, the therapist may be able to see more clients in a given time period making them more productive. No studies to date have looked at the value of treatment time saved when using a concurrent treatment approach compared to other multimodal approaches.

Method

Study Design

This was an experimental study using a pretest-posttest randomized group design in which study participants with a diagnosis of CR were treated with either the concurrent use of ICT and NMTs with exercise or a multimodal approach using sequential ICT and NMTs and exercise. The experimental group was the concurrent use of ICT and NMT while the control group was the sequential approach. The study took place from July 2018 to June 2020. Prior to participant recruitment, the study was approved by the Institutional Review Board of the University of Indianapolis.

Participants

A convenience sample was recruited from the clinic that the primary researcher worked. Potential participants were referred by a physician's office or self-referred with a chief complaint of neck pain with arm symptoms of pain or numbness, a score of 10 or greater on the Neck Disability Index (NDI) and a score of 2 or greater on the numeric pain rating scale (NPRS). In addition, participants must be at least 18 years of age and diagnosed with CR. This diagnosis of CR was based on the clinical prediction rule determined by Wainner et al. (2003). Patients were excluded if they presented with one or more of the following: 1) evidence of cervical myelopathy, bilateral upper extremity involvement, or medical red flags (fracture, spinal tumor, rheumatoid arthritis, osteoporosis or long-term steroid use 2) currently pregnant, 3) recent history of cervical trauma, 4) evidence of instability, 5) evidence of vascular compromise, 6) previous surgery on the cervical spine, or 7) recent cervical injection in the past six weeks. These criteria have been used in similar studies (Cleland et al., 2005, Raney et al., 2009, Young et al., 2009). No restrictions were placed on gender or ethnic composition.

Sample Size. An a priori sample size estimation was conducted using G*Power, version 3.1 (Faul, Erdfelder, Lang, & Buchner, 2009). The calculation was based on using a repeated measures ANOVA, within-between interaction test with two groups and two measurements and the following parameters, two-tailed test, alpha of .05, power of .80, and a small effect size of 0.15. From the calculation it was estimated that a minimum of 90 participants were needed for this study to be appropriately powered. Because this study was a student doctoral project the primary researcher did not have the time or resources to obtain a sample of that size in a reasonable and acceptable time period. Therefore, this study was underpowered. However, similar studies have used smaller sample sizes ranging from 27-60 (Jellad et al., 2009; Khatwani, Yadav, & Kalra, 2015; Kim, Chung, & Jung, 2017; Kumar et al., 2017; Lamba, Rani, Gauer, Upadhyay, & Bisht, 2012; Savva et al., 2016,). Based on the clinical population, it was estimated that a maximum sample size of 50 (25 in each group) would be recruited. To date, no study to date has looked at comparing the sequential approach and concurrent approach in the context of a multimodal treatment intervention; therefore, even an underpowered study should add significant information to the base of knowledge.

Data Collection

Data was collected from the initial visit (pre-treatment) and at the final visit after the last intervention (post-treatment). The primary researcher was responsible for all data collection. Each participant was assigned a unique study identification number and no participant identifiers were recorded in the Excel file. Data collected for both pre-treatment and post-treatment was extracted from the participant's medical record and entered into the Excel spreadsheet as soon as possible after the initial evaluation and as soon as possible after the last treatment session. Data that was collected pre-treatment include the following demographics: age, gender, weight

(pounds), and duration of symptoms (less than 3 months duration or greater than 3 months duration). The following outcome data was be collected both pre-treatment and post-treatment: cervical ROM (flexion, extension, lateral flexion and rotation), Neck Disability Index (NDI) score, and numeric pain rating scale (NPRS) score. Results of the special testing of the clinical prediction rule (cervical ROM < 60, Spurling test, ULNTT A, and neck distraction test) was collected at the initial evaluation. Post-treatment the treatment time was also collected.

Operationalization of variables. Pain was operationalized by scores on the NPRS. Patient function was operationalized by scores on the NDI and measurements of cervical ROM. Treatment time was defined by the average number of minutes the participant spends in the therapy (total number of minutes divided by number of sessions). A timer was started when a patient began their specific treatment session. The timer remained on until the therapist had ended the session. The timer could have been turned off during a session at the therapist's discretion. Examples may include instances when the patient needed to stop and take a phone call or use the restroom. The timer was restarted once treatment resumed. The timers used for this study are common in clinics and are run on AAA batteries.

Instruments and Equipment

Neck Disability Index. The NDI is a 10 item self-reported measure that includes seven items related to activities of daily living, two items related to pain, and one item related to concentration. Maximum score is 50, but the result is typically expressed as a percentage (0-100%) with higher scores indicating greater disability. For patients with neck pain, the NDI has been shown to have moderate test-retest reliability, ICC = .68; 95% CI [0.30, 0.90] and both minimal detectable change (MDC) and minimal clinically important difference (MCID) have been established, 10.2 and 7.0, respectively (Cleland et al., 2006).

Numeric pain rating scale. The NPRS is a self-reported pain questionnaire that uses an 11point scale (0 meaning 'no pain, and 10 'worst pain imaginable'). For patients with CR, it has been shown to have fair test-retest reliability, ICC = .59; 95% CI [0.14, 0.79] and a MDC of 4.0 and MCID of 2.2 have been established (Young, Cleland, Michener, & Brown, 2010).

Inclinometer and goniometer. A bubble inclinometer was used to collect cervical flexion and lateral flexion and a standard goniometer was used to collect cervical rotation. Interrater and intrarater reliability of a single inclinometer has been found to be good (ICC = .84 - .94 for flexion/extension and ICC = .82 - .92 for lateral flexion (Hole, Cook & Bolton, 1995). For cervical rotation, the standard goniometer has strong intrarater reliability (ICC = .78 to .92), however, it was noted that its interrater reliability is poor (Youdas, Carey, Garrett, & Riddle, 1991).

Procedures

Screening examination. Patients who report to the clinic having neck pain and or arm symptoms were given a standard evaluation by the primary researcher as part of the patient's initial evaluation. This examination is part of standard care at the clinic and no part of it was being done for research purposes only. During the evaluation, special tests were performed that determined a diagnosis of CR. The diagnosis was based on the following clinical presentation: patients who test positive in at least 3 of 4 criteria based upon the clinical prediction rule determined by Wainner et al. (2003). The tests are: 1) Spurling test A, 2) neck distraction test, 3) upper limb tension test A, and 4) cervical ROM. For Spurling Test A, the patient was seated with the therapist behind the patient. The neck was passively flexed toward the symptomatic side and the therapist provided a downward force of approximately 7 kg through the patient's head. A positive test was reproduction of the patient's symptoms. The neck distraction test; with the

patient supine, the therapist grasped the head and occiput and provided a distraction force of approximately 14 kg. A positive test was a reduction in the patient's symptoms. For the Upper Limb Tension Test A, the patient was positioned supine and the examiner placed the patient's upper extremity into (1) scapular depression, (2) shoulder abduction, (3) forearm supination, wrist and finger extension, (4) shoulder external rotation, (5) elbow extension, and (6) contralateral then ipsilateral cervical lateral flexion. A positive test included any of the following: symptom reproduction, greater than 10-degree difference in elbow extension when compared to the contralateral extremity, and an increase in symptoms with contralateral cervical side-bending or a reduction in symptoms with ipsilateral cervical side-bending. Finally, for cervical rotation measurement, the patient, in a seated position, was asked to rotate their head as far as they can. Using a standard goniometer, the researcher, with the goniometer above the patient's head, measured the motion. Rotation right and left was measured. A positive test was cervical rotation less than 60 degrees on the symptomatic side. This rule has been used in other studies in this patient population (Cleland et al., 2005; Moustafa & Diab, 2014; Savva et al., 2016).

Recruitment. Patients who met the inclusion criteria for the study were recruited by the primary researcher at the clinic he practices. Potential patients were those who presented to the clinic with a diagnosis of neck and or arm pain. Eligibility was determined after the initial examination and the patient was found to be positive on at least 3 of 4 special tests used for the inclusion criteria. After the examination the primary researcher verbally discussed the study with the patient.

Informed consent. Individuals who meet eligibility criteria were asked to join the study. Willing participants were required to sign an informed consent. The primary researcher reviewed

the study's purpose, possible benefits and adverse reactions and what treatments the participant would receive and the anticipated number of treatment visits to expect. Patients were informed the treatments used in the study were considered the standard of care for this patient population and the time frame was be the same or very similar if they declined to be in the study but wanted to continue physical therapy. Patients were made aware the only difference between the sample groups was be if they receive a concurrent intervention of ICT and NMTs. Patients could elect to be in the study at that time and the interventions could begin the same day. However, patients were given until their next scheduled visit to make their decision. Involvement in the study did not require any extra time except for the informed consent (estimated to take 15 minutes) portion.

Group assignment. Using Excel, a random number generator program with numbers 1 through 50 and with two groups (group 1 and group 2) was performed. 50 opaque envelopes, each with a unique study identification number and group assignment was produced. The primary researcher kept a log book by the envelopes. The logbook and envelopes were placed in a secure area with limited access. As participants were recruited, they opened up an envelope. The participant's name assigned study identification number and group assignment was entered into the log book. At the end of each day, the envelopes and log book were stored in the primary researcher's private office in a locked drawer in which only the primary researcher had a key.

Data management. Participant information was entered into an Excel spreadsheet on a password protected laptop. Participant privacy was protected by using randomly generated numbers that were their study identification throughout the study.

Intervention. Participants assigned to the control group received the sequential approach which included exercise, manual therapy, and ICT. The experimental group received the

concurrent approach which included exercise, manual therapy, and concurrent upper extremity NMTs and ICT. Treatments received by participants in both groups were considered standard care with the main difference being changed for research purposes was the order of the treatment received by the experimental group. Participants in both groups were to be seen two times a week for four weeks. The total of number of visits varied based on response to treatment. The therapist for each participant was the primary researcher. The primary researcher had over 24 years of experience in physical therapy, had completed an orthopedic residency, and has board certification in orthopaedic physical therapy.

Control (sequential) group. Each control group participant received an active exercise program, thoracic spine manipulations, NMTs to the cervical spine in the form of lateral glides with the arm in median nerve bias, NMTs to the upper extremity using ULNTT A, and ICT.

Exercises were focused on cervical deep neck flexors, middle and lower trapezius, and serratus anterior muscles. For cervical deep neck flexor strengthening, patients were supine and performed craniocerivcal flexion. The therapist provided supervision and cueing to ensure the patient was not eliciting muscle contraction of the sternocleidomastoid muscle. The goal of the exercise was to hold a contraction for 10 seconds and repeat 10 times. For middle and lower trapezius strengthening the patient was prone with the arm in 90 degrees of abduction for the middle trapezius and in 120 degrees for the lower trapezius. With the arm in external rotation the patient raised the arm off the table and slowly returned. The goal was two sets of 10 and progression included the use of weights at the therapist discretion. The final exercise was wall push-ups. The patient stood facing a wall with the arms at shoulder height on the wall. The patient was be asked to perform a push up ‘plus’ by leaning toward the wall and then pushing away until elbows were fully extended and scapula were protracted. Initial goal was two sets of

10. These exercises were to become the patient's home exercise program. Patients were asked to perform 1 time a day. In addition, the patient was instructed on cervical rotation to each side. In sitting, the patient placed a fist, thumb side up, in their sternal notch. With their chin resting on their thumb, they were asked to slowly turn their head side to side for 10 repetitions. They were instructed to do this two-times per day. The goal was for each patient were to complete all the exercises. The treating therapist used his discretion on when to implement and progress each exercise. These exercises have been used in other similar studies (Cleland, Childs, & Whitman, 2008, Ragonese , 2009, Young, Cleland, Michener, & Brown, 2010).

After the exercise program, each participant received thoracic manipulations to the upper and mid thoracic spine. The technique has been described elsewhere (Cleland et al, 2005). These interventions were designed to address hypomobile motion segments of the thoracic spine. Based on examination findings, the therapist chose which specific segments were to be addressed. After each thrust technique, if an audible cavitation was not heard, the therapist could elect to perform it for a second time. For the upper thoracic manipulation, the patient had their arms clasped around their neck with the elbows close together in front. The therapist partially rolled the patient on their side and placed his manipulative hand over inferior vertebra of the motion segment to be addressed. The patient was then rolled back to supine. The therapist, using his upper body positioned over the patient's arms, provide and high velocity, low-amplitude thrust. For the mid thoracic manipulation, the patient placed their hands across their chest. Using the similar technique through the patient's elbow, the therapist provided a high velocity low amplitude thrust. For the mid thoracic spine, in order to localize the motion segment, the patient may be asked to flex their head off the table. Once the segment was stabilized, the therapist would support the head with their non-manipulative hand (Cleland et al., 2005). If the patient could not

tolerate the positioning or reported increased pain during the intervention, the therapist could elect to forgo this intervention for that session. It was the goal that each patient underwent these manipulations at each treatment session.

After thoracic manipulations, the patient received NMTs to the cervical spine using lateral glides. This technique has been described elsewhere (Cleland et al., 2005). The patient was positioned supine with the therapist at their head. For this technique, the mobilizing hand was on the symptomatic side. The therapist first placed the symptomatic side arm in the position of median nerve bias; arm abducted, shoulder external rotation and wrist and fingers in extension. The specific position was varied based on the patient's tolerance and avoidance of painful stimuli. Grasping and supporting the head of the patient with their non-mobilizing hand, the therapist then placed their mobilizing hand on the motion segment to be targeted and provided oscillatory translational glides away from the painful side (for example, if the right side was considered the involved side, the therapist placed their mobilizing hand on the right side of the neck). The goal was a grade IV mobilization up to 30 seconds at each targeted segment. The therapist performed 4-6 repetitions at each segment. (Cleland et al., 2005). The technique's purpose was to open the facet joint on the involved side (Vincenzio, Neal, Collins & Wrigth, 1999). This technique has been used in multiple studies with similar patient populations (Cleland et al., 2008, Ragonese, 2009)

Next, the patient received upper extremity NMTs in the form of median nerve glides (Cleland et al., 2005). For median nerve mobilization the patient was supine while the therapist sequentially placed the arm to be treated in scapular depression, shoulder abduction, full external rotation, elbow flexion and wrist and hand extension. The initial treatment was a 'slider' technique. As the therapist extended the arm, he moved the patient's hand and fingers into less

extension. This technique has been shown to increase nerve bed motion but not increase strain on the nerve root (Coppieters & Butler, 2008; Dilley et al., 2005). The movements were slow and lasted for approximately 30 to 60 seconds. As the patient tolerated the motion without pain, the therapist changed to a 'tensioner' technique which maintained the hand and fingers in full extension while the patient's elbow was slowly extended. This progression of neuromobilization has been shown to be effective in the treatment of patients with CR (Cleland, Childs, & Whitman, 2008; Efstathiou et al., 2015; Ragonese, 2009).

The final intervention the patient received was supine ICT. Each patient received ICT for 15 minutes. The machine was inworking order and had been calibrated on a yearly basis. For the initial session, the patient's head was positioned in 25 degrees of flexion. The initial setting was 15 pounds and could be incrementally progressed each session to patient's tolerance. The focus was on reduction of symptoms in the arm and or neck. The on off cycle time was set for 40 seconds on and 10 seconds off. Minor adjustments to neck angle were made based on patient's preference. Studies have supported ICT for this patient population but the amount of pull, angle of pull and time on machine varied (Cleland et al., 2008; Fritz et al., 2014; Moeti & Marchetti, 2001; Moustafa & Diab, 2014). Therefore, the final adjustments were left to the therapist's discretion on patient tolerance and impact on symptoms.

Experimental (concurrent) group. The experimental group included the same exercises, thoracic manipulations, and cervical lateral glides. They were performed in the same order. The only difference was the experimental group had the concurrent use of upper extremity NMTS with ICT. After cervical lateral glide interventions, the participant was started on ICT as described in the control group section. During the pull cycle of ICT, the therapist performed the upper extremity NMTs described earlier in the control group section. The patient received

approximately 30 seconds of treatment during the on cycle with a 10 to 20 second rest period. The therapist performed up to 8 cycles during the ICT. As in the control group, the initial treatment consisted of sliding techniques. As patient's tolerance improved, the treatment was progressed to a tensioning technique. A similar intervention has been done previously in the literature (Kumar et al., 2017).

Data Analysis

Descriptive statistics were conducted on the total sample and between and within groups. Nominal data are reported as frequencies and percentages. Nominal data were compared using Fisher's exact tests. Interval and ratio data are reported as means and standard deviations. Interval and ratio data comparisons between groups were analyzed using independent *t* tests. Paired *t* tests were used to compare interval and ratio data within the concurrent approach group and within the sequential approach group. Effect sizes (ES) were calculated and interpreted based on recommendations by Cohen (1988) with an effect size 0 - .20 = small, .50 = medium; .80 and higher = large. That means an ES less than .20 is considered negligible. Data were analyzed using IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY). Significance level of less than .05 was considered statistically significant.

Results

Fourteen participants; six in the concurrent group and eight in the sequential group were originally enrolled in the study. Two participants in the sequential group did not complete the study, citing work obligations and difficulty being compliant with therapy sessions so their results were not included in the final analysis. Therefore, the final sample size was 12. Seven (58.3%) males and 5 (41.7%) females participated in the study. The mean (standard deviation) age of participants was 60.67 (13.02) years, time from injury was 158.08 (218.57) days, and

number of visits per participant was 7.92 (2.78). The mean weight of participants was 200.75 (50.74) pounds and height was 66.58 (3.63) inches. Demographic and outcome descriptive statistics for each study participant is presented in Table 1.

Group Comparisons

Participant characteristics between groups. Independent *t* tests were conducted to determine if there were statistically significant differences in gender, age, weight, height, time since injury, and number of visits between the concurrent and sequential groups. There was not a statistically significant difference in sex between the concurrent and sequential group (males: 42.9%, 57.1%, respectively; $p = 1.000$). There was not a statistically significant difference between the concurrent group and the sequential group for age, $t(10) = 1.02$, $p = .331$, weight $t(10) = -0.41$, $p = .690$, height $t(10) = -0.23$, $p = .824$, time since injury $t(10) = -1.55$, $p = .177$, or number visits $t(10) = -1.41$, $p = .189$. Details of the results can be found in Table 2.

Outcomes between groups. The mean time per visit, pre-intervention and post-intervention NDI scores, and pre-intervention and post-intervention NRPS scores were compared between the concurrent and sequential groups using independent *t* tests. There was a statistically significant difference in the mean treatment time per visit between the concurrent and sequential groups, $t(10) = 3.95$, $p = .007$. However, there was not a statistically significant difference in NDI scores pre-intervention and post-intervention between the groups, $t(10) = 1.13$ $p = .283$, ES = 0.66; $t(10) = 0.62$, $p = .547$, ES = 0.40; respectively or pre-intervention and post-intervention for NPRS scores, $t(10) = 0.69$, $p = .508$, ES = 0.36; $t(10) = 0.91$, $p = .384$, ES = 0.53; respectively. Details of all comparisons and ES are found in Table 3.

Outcomes within groups. NDI and NPRS scores along with cervical ROM measurements were compared within the concurrent group and within the sequential group using

paired *t* tests. There were statistically significant differences in NDI scores and NPRS scores over time for the concurrent group, $t(5) = 3.94$, $p = .011$, ES = 1.61; $t(5) = 4.11$, $p = .009$, ES = 1.68; respectively. The mean difference for NDI scores was 21.00 and the ES indicated a large effect of the intervention. This was greater than the MDC and MCID (10.2 and 7.0, respectively) making the improvement in function both statistically and clinically significant. The mean difference for the NPRS scores was 4.34 which is was greater than the MDC and MCID (4.0 and 2.2, respectively) making the improvements in pain clinically significant in addition to being statistically significant. With regards to cervical ROM, there were statistically significant differences from pre-intervention to post-intervention in the concurrent group for flexion, right lateral flexion and right rotation, $t(5) = 2.98$, $p = .031$; $t(5), = 4.03$, $p = .010$; $t(5) = 3.43$, $p = .019$; respectively. The ES ranged from 1.22 to 1.65 indicating a large effect for the intervention. The sequential group also had statistically significant change from pre-intervention to post-intervention for NDI and NPRS scores, $t(5) = 2.68$, $p = .044$, ES = 1.10; $t(5) = 5.11$, $p = .004$, ES = 2.09 respectively. With mean differences in NDI scores of 17 and NPRS scores of 4.83, results were both clinically and statistically significant and the ES indicated a large effect of the intervention for the sequential group as well. The sequential group had statistically significant difference from pre-intervention to post-intervention ROM for only right rotation, $t(5) = 3.58$, $p = .016$, ES = 1.46. Details of the comparisons and ES are found in Table 4.

Discussion

The purpose of this study was to determine if the use of concurrent ICT and NMTs would be more effective in reducing pain and improving function based on NDI scores compared to the sequential use of ICT and NMTs when performed in a multimodal approach to patients with CR.

An additional purpose of this study was to determine if there was a significant difference in treatment time between the two treatment approaches.

Traction and more specifically ICT, has been shown to be effective in the treatment of patients with CR (Aydin &Yazicioglu 2012; Fritz et al, 2014; Moetti & Marchetti 2001). Along with other physiological effects, mechanical traction is thought to increase the diameter of neuroforaminal openings (Bellew et al., 2013). NMTs through joint positioning, specific maneuvers performed at the neck, or maneuvers performed to the involved upper extremity, are thought to restore normal mechanics between the involved nerve complex (nerve root and portion of the nerve involved) and surrounding tissue (Efstathiou, Stefanakis, Savva, & Giakas, 2015) causing a reduction in edema and improvement in nerve gliding. NMTs have been shown to reduce pain and improve function in patients with CR (Allison &Hall 2002; Nar 2014; Nee et al., 2012; Ragonese, 2009). It may be expected then, that when used concurrently, cervical traction would 'prepare' the impaired cervical nerve root for mobility by increasing the diameter of the lateral foramen allowing the affected nerve root more space when NMTs are implemented. With this combined treatment, patients may have significant improvement in pain and disability.

The current study results are in accordance with previous studies on the use of concurrent traction and NMTs (Khatwani, Yadav, & Kalra, 2015; Kim, Chung, & Jung, 2017; Kumar et al., 2017; Savva et al., 2016,). The overall treatment effect of the concurrent approach was not significantly different than the sequential treatment approach in cervical traction and neural mobilizations in patients with CR. However, results of this randomized control trial indicated the concurrent approach required less treatment time per visit compared to the sequential approach.

Patients treated with a concurrent approach had significant reduction in pain and disability compared to other treatment interventions (Khatwani et al., 2015, Kim et al., 2017,

Kumar et al., 2017) or a control group (Savva et al., 2016). The NDI and NPRS were used in each of the studies making it easier to compare. However, a significant difference between the current study and the studies by Khatwani et al. (2015), Kim et al. (2017), and Savva et al. (2016) was the type of traction. In the three studies mentioned, manual traction was used with NMTs. The studies using manual traction with NMTs required two treating clinicians. In addition, manual traction was not able to precisely control for specific traction weight, angle of the pull, or on off cycle which are present in the use of ICT. Therefore, it was difficult to compare the current study's outcomes with those that used manual traction.

The integration of using ICT with NMTs was a new intervention technique only seen in the study by Kumar et al. (2017). The current study closely resembles the study by Kumar et al. (2017) in that the researchers compared patients who underwent concurrent ICT and NMTs to another treatment group or groups. Also, Kumar et al. (2017) found that after 4 weeks and 12 treatment sessions, the group receiving concurrent ICT and NMTs had statistically significantly differences over the traction only group and NMTs group in pain and disability. Similarly, results from the current study found that the concurrent group had statistically significant decreased pain and disability. In addition to being statistically significant, the concurrent group's differences in pain and disability were clinically relevant and had large effect sizes (ES = 1.61, NDI; ES = 1.68, NPRS). The impact of the concurrent intervention provides clinical significance as well as statistical significance. As reported by Kumar et al. (2017), NDI scores for the experimental group had a 59.7% improvement (49.40 pretreatment to 19.90 posttreatment) and the current study had a 66% improvement in NDI scores (32.67 pretreatment to 11.00 posttreatment). For NPRS scores, Kumar et al. (2017) found a 71% improvement in scores (6.14 pretreatment to 1.76 posttreatment), whereas the current study had a 61% improvement in scores (7.17

pretreatment to 2.83 posttreatment). Both the current study one and the one by Kumar et al. (2017) support the use of a concurrent approach in the treatment of patients with CR to reduce pain and improve function.

While there are similarities between this study and the Kumar et al. (2017) study, there are also differences. One distinction is that the average age for the experimental groups differed by 14 years, current study 64.5 years, Kumar et al. study 50.5 years. A mostly likely reason for the difference in age is that the current study included individuals 18 years and greater while Kumar et al., (2017) included patients only between the ages of 45 to 55 years. Although the fourth and fifth decade of life is the most common age range for the diagnosis of CR (Goode, Freburger, & Carey, 2010; van Hulst,van Oostrom, Ostelo, Verschuren, & Picavet, 2016), researchers of the current study thought it was important to expand the age range as it more closely represents patients treated in an outpatient clinical setting. Results of the current study found significant improvement in pain and disability of patients which adds to the findings from Kumar et al. (2017). With no negative effects reported in the older study participants for either study, it may allay therapist concerns on the safety and tolerance of using these treatment techniques in this population.

A second difference between Kumar et al.'s (2017) study and this study is the treatment parameters used. Researchers have reported employing different parameters in their studies supporting ICT (Fritz et al., 2014; Jellad et al., 2009; Moustafa & Diab, 2014). Kumar et al. (2017) used a 15-degree angle of pull, an on/off cycle of 60:30sec, with a treatment time of 9 minutes. The current study used a 25-degree angle of pull, an on/off cycle of 40:10sec, and a 15-minute treatment time. Both studies showed significant improvement in outcomes regardless of some of the parameters used, suggesting that treating clinicians may have options when

determining how to use ICT. The current study found that one optional parameter that seems to not negatively affect patient outcomes is the positioning patients for their comfort. It is also possible that increasing patient comfort may result in improved patient satisfaction. With regards to the parameters of NMTs techniques, both studies started with sliding techniques and progressed to tensioning techniques to patient tolerance.

A third important difference between the two studies was the treatment provided to the groups not receiving the concurrent approach. For the current study, participants performed exercises and the treating clinician performed manual therapy to the cervical spine in the form of lateral glides and the thoracic spine in the form of manipulations. In contrast, Kumar et al. (2017) limited their participants to one specific parameter for the duration of the study; ICT group and an NMTs group. This makes comparisons difficult as, for the current study, there was an expectation of improvement in the control group.

The concurrent group in the current study was able to demonstrate significant improvement in less treatment sessions when compared to the Kumar et al, (2017). The average number of visits in the concurrent group was 6.83 (range 3 to 10 visits). Kumar et al. (2017) had patients attend 12 visits. Patients in the concurrent group of the current study used 43% less visits per patient when compared to Kumar et al, (2017). This finding was also lower when compared to the sequential group in the current study (6.83 visits concurrent and 9.00 visits for the sequential group). Patients showing significant improvements in pain and disability in less time than other interventions may make the current study interventions valuable in the clinic setting. One benefit to participants in the current study was the addition of exercise and manual therapy. These additions may have increased the response and decreased the number of visits required.

As reported, the current study was unable to detect a significant difference in pain and disability between the concurrent and sequential group. The sequential group, acting as the control group in the current study, was provided treatment interventions shown by several researchers to be effective in the treatment of patients with CR (Boyles, Toy, Mellon, Hayes, & Hammer, 2011; Cleland et al., 2005). The sequential group received the same interventions that the concurrent group. The multimodal approach used in the current study may be one reason that both groups significantly improved. A clinical impact based on ES for some variables could be argued. For the NDI, the pre-intervention scores were not significant (p = .283; ES = 0.66 [medium]). Post-intervention between group differences for the NDI was also not significant (p = .547; ES = 0.36 [small]). However, the ES change from medium to small indicates that the gap between the two groups closed with the concurrent group having a greater change in score (21-point change for concurrent and 17 point change for sequential). A similar change was noted for a possible clinical relevance with regards to lateral rotation to the right and left. Pre-intervention ES for lateral rotation right and left were 0.93 (large) and 0.30 (small) respectively. Post-intervention there was a decrease in ES from 0.93 to 0.66 (medium) for right lateral and from 0.30 to 0.10 (negligible) for left lateral rotation. These decreases in ES indicate that the concurrent groups' participants had a greater increase in ROM compared to the sequential group. The concurrent group had multiple motions with improvement whereas the sequential group had one. One explanation for the multiple motions of improvement in the concurrent group compared to only one motion in the sequential group could be that the concurrent approach, using improvements in neuroforaminal opening simultaneous with NMTs to reduce pressure on the exiting nerve root, was more effective at reducing pain making it easier for the patient to move the neck. Studies looking at ROM as an outcome reported similar ROM improvements (Kim et

al., 2017; Savva et al., 2016). Savva et al. (2016) documented rotation and lateral flexion to the painful (ipsilateral) and non-painful (contralateral) sides. The current study used right and left labels without consideration of which was the involved side.

One of the unique findings in the current study is the significant difference in time found between groups. The concurrent approach used less time per visit (41.83 minutes concurrent group to 49.17 minutes sequential group) which may be an aspect that makes it more desirable in the clinical setting. No previous studies in the published literature that were reviewed included treatment time as a parameter. Due to this, it is difficult to discuss what would be the amount of difference in time that would be considered a clinically significant difference.

With so few participants in the current study, there are limitations to generalizing study results. However, there is a benefit to being able to describe specific differences between participants. For example, in the concurrent group, patients 3 and 5 had significant decreases in NDI scores (32 to 0 for patient 3 and 26 to 0 for patient 5), and NPRS scores (3 to 1 for patient 3 and 7 to 0 for patient 5) scores. Patient 3 and 5 also had the shortest time from injury (26 days for patient 3 and 14 days for patient 5) to the start of physical therapy interventions. This could indicate the benefits of initiating physical therapy soon after the onset of symptoms to achieve the greatest benefit. Horn, Brennan, George, Harman, and Bishop (2016) found patients with neck pain who received early physical therapy (within 4 weeks of onset) had better outcomes in NDI scores and NPRS scores compared to those having a delay in physical therapy. In contrast, patient 4 of the concurrent group had the longest time from injury (180 days). Patient 4 reported chronic neck issues, but had a recent exacerbation of symptoms which included pain in the right shoulder and scapular region. In addition, patient 4 was the only patient who tested negative on the distraction test in the concurrent group. Perhaps, a negative distraction test, may indicate a

lesser response to ICT. At time of discharge, patient 4 continued to report mild symptoms in his right upper extremity.

Individuals in their 40s and 50s are considered the most at-risk age group for the onset of CR (Goode et al., 2010). Patients 1 and 5 were the youngest patients in the experimental group (42 and 57 years of age). They both had excellent outcomes including 0 out of 10 pain reported on the NPRS. Patient 6 was 71 years of age and showed least improvement in the concurrent group with regards to change in both NDI scores (no change) and NPRS scores (2-point change). Patient 6 reported having a prior injury to his upper back which resulted in chronic issues. Perhaps the impact of upper thoracic issues impacted the benefits of thoracic manipulation. After 4 visits, patient 6 requested to follow-up with his physician and was sent for further testing and imaging.

Limitations

A limitation to the current study is the small sample size, which increased that chances of making a type II error. Post hoc power calculations showed that none of the non-significant outcomes measured post-intervention were sufficiently powered with the highest power of 0.36 found for cervical ROM left rotation and the lowest power of 0.05 for cervical ROM left lateral rotation. For the primary outcomes of NDI and NPRS scores, post hoc power calculations were 0.09 and 0.13 respectively (Faul, Erdfelder, Buchner, & Lang, 2009). Not having been sufficiently powered, it is difficult to recommend the concurrent approach over the sequential approach. One advantage of the study was that participants were randomized in which treatment group they received. In addition, the treatment techniques are standardized and shown to be effective in the treatment of patients with CR. One drawback was the treating clinician and evaluating clinician were the same. Bias could have been a factor in testing procedures for CR.

However, keeping to one clinician did improve internal validity Future studies should look to compare the concurrent approach to the sequential approach in an appropriately powered setting to determine if it is more effective than the sequential approach. Nevertheless, this study does add to the limited information currently known about the concurrent approach. In addition, the current study's novel analysis on treatment time difference may lead to future studies to report on benefits of reduced treatment time and its impact on therapist productivity or possible health care savings for the patient.

Conclusion

Although no significant differences were found in the current study on outcomes between group settings, within group differences in the concurrent approach exhibited statistically and clinically meaningful differences in pain and disability. In addition, the current study most closely resembled a clinical setting. Practitioners may look to these results more favorably and have more confidence on the effectiveness of the interventions. The results found is this study suggest that the concurrent approach may be an effective intervention in the treatment of patients with CR.

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Table 1

Demographics and Pre-Intervention and Post Intervention Outcomes by Study Participants

Study Participant	Age (years)	Sex	Days from Injury	Pre NDI	Post NDI	Pre NPRS	Post NPRS	Number of visits
Concurrent								
1	42	Female	60	46	8	8	0	8
2	73	Female	60	40	24	8	5	10
3	71	Female	26	32	0	3	1	8
4	73	Male	180	32	14	7	3	8
5	57	Male	14	26	0	7	0	3
6	71	Male	56	20	20	10	8	4
Sequential								
1	51	Female	720	30	16	6	4	7
2	42	Male	28	14	0	4	0	5
3	42	Female	364	16	10	8	3	11
4	70	Male	21	16	8	5	1	9
5	68	Male	8	50	2	9	0	12
6	68	Male	360	24	12	6	1	10

Note. Pre = pre-intervention; post = post-intervention; NDI =neck disability index; NPRS = numeric pain rating scale

Table 2

Comparison of Descriptive Statistics Between Concurrent and Sequential Groups

	Concurrent Group *n* = 6	Sequential Group *n* = 6	
	M (*SD*)	*M* (*SD*)	*p*
Age (years)	64.50 (12.58)	56.83 (13.40)	.331
Weight (pounds)	194.50 (42.32)	207.00 (61.48)	.690
Height (inches)	66.33 (3.62)	66.83 (3.97)	.824
Time since injury (days)	66.00 (59.11)	250.17 (285.06)	.177
Number of visits	6.83 (2.71)	9.00 (2.61)	.189
Treatment time per visit (minutes)	41.83 (1.47)	49.17 (4.31)	.007

Table 3

Comparison of Outcomes Between Concurrent and Sequential Groups

	Concurrent Group (n = 6)	Sequential Group (n = 6)		
	M (*SD*)	*M* (*SD*)	*p*	Effect Size
Treatment time	41.83 (1.47)	49.17 (4.31)	.007	2.28 (large)
Pre-Intervention				
NDI score	32.67 (9.35)	25.00 (13.67)	.283	0.66 (medium)
NPRS score	7.17 (2.32)	6.33 (1.86)	.508	0.40 (small)
Flexion	47.17 (17)	49.00 (10.70)	.574	0.34 (small)
Extension	42.50 (15.41)	46.17 (13.32)	.669	0.26 (small)
Right lateral	24.83 (10.98)	33.33 (6.80)	.138	0.93 (large)
Left lateral	28.83 (6.91)	30.83 (6.46)	.616	0.30 (small)
Right rotation	49.00 (11.83)	57.50 (20)	.367	0.55 (medium)
Left rotation	49.00 (6.00)	52.83 (14.22)	.556	0.35 (small)
Post-Intervention				
NDI score	11.00 (10.10)	8.00 (6.07)	.547	0.36 (small)
NPRS score	2.83 (3.19)	1.50 (1.64)	.384	0.53 (medium)
Flexion	55.17 (7.65)	56.83 (7.31)	.708	0.22 (small)
Extension	48.33 (9.91)	51.17 (14.41)	.700	0.23 (small)
Right lateral	32.83 (9.17)	38.83 (9.04)	.280	0.66 (medium)
Left lateral	35.00 (6.69)	34.33 (6.41)	.864	0.10 (negligible)
Right rotation	56.17 (9.24)	65.17 (8.84)	.115	1.00 (large)
Left rotation	53.83 (9.07)	63.00 (8.94)	.108	1.02 (large)

Note. NDI = neck disability index, NPRS = numeric pain rating scale, Treatment time = minutes

Table 4

Comparison of Outcomes Within the Concurrent Group and Within the Sequential Group

	Pre-Intervention (n = 6)	Post-Intervention (n = 6)		
	M (*SD*)	*M* (*SD*)	*p*	Effect Size
Concurrent Group				
NDI score	32.00 (9.35)	11.00 (10.10)	.011	1.61 (large)
NPRS score	7.17 (2.32)	2.83 (3.12)	.009	1.68 (large)
Flexion	45.17 (12.09)	55.17 (7.65)	.031	1.22 (large)
Extension	42.50 (15.41)	48.33 (9.91)	.134	0.73 (large)
Right lateral	24.83 (10.98)	32.83 (9.17)	.010	1.65 (large)
Left lateral	28.83 (6.91)	35.00 (6.69)	.051	1.04 (large)
Right rotation	49.00 (11.83)	56.17 (9.24)	.019	1.40 (large)
Left rotation	49.00 (6.00)	53.83 (9.06)	.178	0.64 (medium)
Sequential Group				
NDI score	25.00 (13.67)	8.00 (6.07)	.044	1.10 (large)
NPRS score	6.33 (1.86)	1.50 (1.64)	.004	2.09 (large)
Flexion	49.00 (10.70)	56.83 (7.30)	.082	0.89 (large)
Extension	46.17 (13.32)	51.17 (14.41)	.087	0.87 (large)
Right lateral	33.33(6.80)	38.83 (9.04)	.238	0.55 (medium)
Left lateral	30.83 (6.46)	34.33 (6.41)	.150	0.69 (medium)
Right rotation	55.50(11.98)	65.17 (8.84)	.016	1.46 (large)
Left rotation	52.83 (14.22)	63.00 (8.94)	.056	1.01 (large)

Note. NDI = neck disability index, NPRS = numeric pain rating scale