

THE EFFECTS OF KINESIO® TAPE ON NECK DISABILITY AND PAIN

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Rebekah Elizabeth Zerbe

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The Effects of Kinesio® Tape on Neck Disability and Pain

By

Rebekah Zerbe

The Supervisory Committee certifies that this thesis complies with North Dakota State University's regulations and meets the accepted standards for the degree of

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SUPERVISORY COMMITTEE:

Dr. Katie Lyman

Chair

Dr. Bryan Christensen

Ms. Karla Haug

Approved:

July 9, 2021

Date

Dr. Yeong Rhee

Department Chair

ABSTRACT

Kinesio® Tape is a proposed treatment to improve neck disability due to its advertised benefits such as decompression of tissue, facilitation of muscles, and improvement in range of motion.¹⁻⁵ While the advertised benefits appear promising and applicable for the treatment of neck pain, scientific evidence on its effectiveness is limited. The purpose of this study was to determine if Kinesio® Tape could alleviate neck pain and improve cervical range of motion on a mask-wearing population. Thirty adults with neck pain participated in the study. Active cervical range of motion and pain were recorded before and after application of Kinesio® tape over the cervical spine. Participants experienced a significant increase in cervical left lateral flexion ($p=.014$), cervical extension ($p=.093$), and right rotation ($p=.059$) in the taped condition compared to no tape. Additionally, pain decreased with application of the tape with ($p<.001$) and without movement ($p=.001$).

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CHAPTER 1. INTRODUCTION

1.1. Overview of the Problem

The 2010 worldwide prevalence of neck pain was estimated at 4.9 percent,⁶ and it has been estimated to be even higher in the United States at 13.3 percent.⁷ The negative impacts of neck pain can affect an even greater percentage of the population by influencing families, communities, healthcare systems, and businesses.⁶ Many outside risk factors and exacerbating pathomechanics exist including forward neck posture and decreases in cervical range of motion.^{8–10} Additionally, the global COVID-19 pandemic has created a new trigger for neck pain secondary to mask wearing.¹¹ With an uncertain end to the pandemic and continued mask mandates at indoor functions where social distancing cannot be maintained, a paramount need for immediate, safe, and effective neck pain treatments has been created.

Research regarding treatment for neck pain has been ongoing for years with numerous studies outlining potential successful options.^{2–4,12–15} However, many of these studies suggest long-term rehabilitative programs involving weeks or months of dedication.^{12,16–18} While these exercise regimens have been validated for long-term treatment and future prevention of neck pain, immediate solutions to reduce symptoms and increase quality of life for mask-related and non-mask-related neck pain are a necessity.

One possible treatment suggested for neck pain and neck pain-related disorders is Kinesio® Tape, an elastic and skin-like tape advertised to assist with tissue alignment, edema removal, and to increase range of motion.^{1–4,15} By facilitating underactive muscles commonly associated with forward head posture and neck pain, which are the upper cervical extensor muscles, the tape has been hypothesized to alleviate neck pain symptoms and improve range of motion.⁵ However, multiple taping procedures exist for the treatment of neck pain. To date,

research has been scarce concerning the validation and comparison of these methods of taping to decrease neck pain, increase cervical range of motion, and correct forward head posture.

The immediate effects of Kinesio® Tape on neck pain and disability have been quantified effectively using the numerical pain rating scale (NPRS) for perceived pain and two-dimensional motion analysis of action cervical range of motion (ACROM). These measurement techniques are both non-invasive and validated for both clinical and research use.^{19–24}

1.2. Statement of Purpose

The purpose of this study was to determine if Kinesio® Tape could alleviate neck pain and improve cervical range of motion on a mask-wearing population. The effects were examined by changes in ACROM and pain rating on NPRS. Additional demographic information was collected with a mask-associated pain questionnaire. The mask-associated pain questionnaire was adapted from the Ong et al., 2020¹¹ study on Headaches Associated With Personal Protective Equipment (HAPPE).

1.3. Research Question

Q₁: To what extent does Kinesio® Tape change degrees of motion of the cervical spine? Subsequently, to what extent does Kinesio® Tape alter perceived neck pain?

1.4. Definitions

Kinesio® Tape, Tex Gold FP: is a latex free, 100% cotton elastic strand that measures approximately the same thickness as the epidermis of the skin. When properly applied, the thickness is proposed to limit the body's perception of weight and avoid sensory stimuli.⁵ It has a heat activated adhesive and can remain effective on the skin for up to 72 hours.⁵

Two-Dimensional Motion Analysis: analyzes simple and complex movements with body markers and video from a single camera. The Dartfish® software for Windows can use the video input to generate values based on the location of a marker to calculate ranges of motion.²⁵

Neck pain: is pain in the neck with or without pain referred into one or both upper limbs that lasts for a least one day.⁶

1.5. Limitations

Based on the time constraints and human subject limitations during the pandemic, there were limitations associated with the design of this research project. Due to the use of convenience sampling at a mid-sized American university, generalization to a large age demographic was a limitation. For the same reason, there was a regional limitation to this study. Another limitation was the precise stretch applied to the Kinesio® Tape was not measured. This was minimized since the researcher applying the tape was a Certified Kinesio® Taping Practitioner; however, the exact patient positioning and tape stretch may have varied slightly from participant to participant. Due to the lack of counterbalancing in this study, the effect of performing each range of motion movement six times (three at baseline and three post-tape application) could have affected the range of motion data. However, range of motion baseline data was necessary to determine effectiveness of the tape on reducing neck disability. Finally, the sample size was only 30 participants, which limited the power of the study results. Future studies on this topic should alter the methodology to consider for the provided limitations of the current study.

1.6. Delimitations

A delimitation of the study was the length of time the tape was left on the participant. Only the immediate effects 20 minutes after application of the tape were measured even though

Kinesio® Tape advertises effects that last up to 72 hours.⁵ The reasoning for this was due to the evaluation of similar research studies and their results. A research study on the effects of Kinesio® Tape on shoulder pain and range of motion documented increases in pain free shoulder range of motion immediately after tape application.²⁶ Additionally, in a similar study design, improvements in ACROM were observed immediately after tape application.² A second delimitation was the tape procedure used in this study. The Kinesio® Taping Association International (KTAI) technique for taping underactive muscles does not have substantial published scientific validation, but it is a commonly cited technique in literature for Kinesio® Tape neck pain treatment.²⁻⁴ The combination of the underactive muscle taping method and the web space correction was a delimitation in determining which technique caused the results. However, we chose to use the most commonly cited taping technique to alleviate neck pain found through an extensive literature review on the topic.²⁻⁴

1.7. Assumptions

It was assumed the participants accurately reported neck pain both before and after treatment. It was also assumed participants would report any discomfort, such as itching or burning, associated with the tape application.

1.8. Variables

The dependent variables in this study were the measurement of ACROM and pain on a 11-point NPRS post-application of the Kinesio® Tape muscle facilitation method. The independent variable in this study was the Kinesio® Tape application.

1.9. Significance of the Study

Neck pain has continuously affected a large demographic of people nationally⁶ and may only be worsening from the required use of masks during the COVID-19 pandemic.¹¹ The

emotional and financial strains of neck pain and disability continue to plague high-risk populations such as healthcare workers.^{6,7} The use of Kinesio® Tape is a cost effective, noninvasive option, which can be employed to relieve patient-perceived pain and increase ACROM. Kinesio® Tape's popularity has been increasing in the medical field²; however, published research is lacking and its effectiveness can therefore be controversial. The research from this study aids in uncovering the efficacy of Kinesio® Tape for the treatment of neck pain and disability.

CHAPTER 2. LITERATURE REVIEW

The substantial disability and economic consequences caused by neck pain, chronic or acute, affects a large number and demographic of people worldwide. The universal problems caused by neck pain include negative impacts on families, communities, healthcare systems, and businesses.⁶ These results make the need for risk factor identification and treatment a highly researched topic in literature today. Kinesio® Tape has been suggested as a possible treatment for neck pain and neck pain-related disorders based on its skin-like properties that are advertised to provide benefits such as tissue alignment, edema removal and ability to increase range of motion.^{1-4,13,26} However, multiple taping procedures exist for the treatment of neck pain. To date, research is lacking on the validation and comparison of these methods of taping for the purpose of decreasing neck pain, increasing active cervical range of motion, and correcting forward head posture.

2.1. Neck Pain Epidemiology

2.1.1. Definition

The definition of neck pain is broad and varies between different sources of literature. The most universally accepted definition is set by the Global Burden of Neck Pain 2010 study (GBD 2010) and is based off The Bone and Joint Decade 2000-2010 Task Force on Neck Pain definition. It defines neck pain as “pain in the neck with or without pain referred into one or both upper limbs that lasts for a least one day”.^{6 (p1309)}

2.1.2. Prevalence

The prevalence of neck pain appears to be increasing in the general population; however, it is difficult to estimate the exact incidence of neck pain worldwide due to the episodic nature of the condition. The best assessment made by the GBD 2010 estimates the prevalence of neck pain

to be 4.9% worldwide (95% CI: 4.6-5.3%).⁶ The highest prevalence is in North America, predominantly in high income regions, at 6.5% (95% CI: 5.6-7.5%), followed closely by western Europe at 6.3% (95% CI: 5.8-6.8%).⁶ In addition to regional discrimination, neck pain commonly affects high income countries more than low-income.²⁷ In the United States the estimated annual neck pain incidence of 13.3%.⁷ Comparatively, to the lowest prevalence is 3.3% in South America (95% CI: 2.8-4.0%).⁶

The increasing prevalence of neck pain poses a threat to healthcare costs and disability. In fact, neck pain is ranked as the fourth greatest contributor to disability globally and 21st in terms of overall burden.⁶ The NHIS found the medical care expenditures for neck pain to approach nearly \$86 billion in the United States yearly.⁷ The rise in incidence of neck pain is of concern due to its direct association to health care costs and disability.

2.1.3. Risk Factors

2.1.3.1. Environmental and Occupational Risks

Many risk factors have been identified as triggers for neck pain with both environmental and occupational components. Occupation has been identified as a primary risk factor for neck pain; however, other risk factors include exposure to tobacco smoke, age, having other comorbidities, poor psychological health, and collision resulting in whiplash-associated disorders (WADs). However, risk factors for neck pain are multifactorial and each risk factor alone, or in combination with another condition, increases the likelihood a person will be burdened by musculoskeletal misalignment.

One population at high risk for developing neck pain in the United States is office workers. The annual incidence of neck pain in office workers is 57%.²⁷ This is most likely related to working environment and ergonomics. Sedentary work over extended periods of time,

specifically as commuters or as office administrators, is an identified cause for the high prevalence.⁷ A cross-sectional study of female office workers (N=333) was conducted and researchers identified relationships between greater Neck Disability Index (NDI) scores and duration of mouse use ($p=.026$; 95% CI .4-5.7), keyboard use ($p=.026$; 95% CI .9-14), computer use before switching to non-computer task ($p=.016$; 95% CI .9,9), and time at workstation before a break ($p=.016$; CI 1.1-10.9).²⁸ In a similar study also investigating female office workers, researchers found that low supervisor support and frequency of mouse use correlated to higher NDI scores.²⁹ Interestingly, studies on the relationship between occupation and neck pain commonly include only female subjects. This may be due to the increased risk of neck pain in women (M=5.8%; 95% CI 5.3-6.4) as compared to men (M= 4.0%; 95% CI 3.7-4.4%).²⁷ One of the hypothesized reasons for this disparity is due to types of jobs females typically occupy.⁷ Females are disproportionally employed in office and administrative support occupations.⁷ Other occupations identified at increased risk for neck pain include health-care providers, transit operators, and military personnel.^{7,27} Thus, occupational hazards are one commonly identified risks for developing neck pain.

Exposure to cigarette smoke is another risk factor explored in association with neck pain. In a study of Norwegian nurse aides exposed to environmental tobacco smoke in childhood, researchers found those exposed had a greater risk for neck pain (OR 1.37; 95% CI 1.03-1.84).³⁰ However, the researchers in this study were most concerned with exposure to smoke as a child as it related to sick leave from work. Also, it is difficult to say with certainty that cigarette smoke exposure as a child leads to neck pain since it may only be indirectly related by another variable. The examination of the relationship between sick leave and neck pain was performed secondary to their primary hypothesis that exposure to cigarette smoke increased risk of long-term sick

leave.³⁰ Cigarette smoke has been associated with an abundance of health concerns, and neck pain should be considered as one possible consequence.

Age is another common and uncontrollable risk factor for neck pain that poses a risk for a large portion of the population. A systematic review of 469 studies was conducted investigating the relationship between age and onset of neck pain. Researchers found that beginning in childhood and adolescence, the risk of developing neck pain increases and peaks in the middle years of life (40 to 49 years-of-life) and then declines.²⁷ A secondary systematic review of 552 studies collaborated the results.³¹ Researchers in this review also found that neck pain peaks in the middle years of life.³¹ Also to note, researchers documented that most people will experience neck pain during their lifetime and will most commonly first experience it during childhood or adolescence.³¹ In further support of age as a contributing factor to neck pain, the NHIS provided similar results with researchers reporting prevalence for neck pain at 8.2% for 18 to 25-year-olds, 12.4% for 26 to 40-year-olds, 15.8% for 41 to 55-year-olds, and 14.3% for 56 to 64-year-olds.⁷ However, as stated above, neck pain risk factors are multifactorial, and therefore, it is difficult to conclude with complete confidence that the risk of neck is increased by age alone and not the association of age with occupation or activity. Another concern with age-related neck pain is how it distributes disability in the population. The disability-adjusted life years (DALYs) calculated by combining years of life lost to premature mortality and years lived with disability indicates 40 to 45-year-olds are the most negatively impacted by neck pain based on highest DALYs.⁶ Based on the available literature, it can be concluded that age is one possible variable feeding into the epidemic of neck pain.

In addition to age, psychological health and multiple comorbidities have been studied as independent risk factors and predictors for developing neck pain. In order to determine incidence

of neck pain in association with individual risk factors, a cross-sectional baseline survey was conducted on the adult general population in the United Kingdom (N=7669) and then followed by a prospective cohort study twelve months later.³² In the follow-up prospective cohort study, researchers found that previous history of neck pain (RR, 1.7; 95% CI, 1.2-2.5), poor self-assessed health (compared to excellent health, RR for good health 1.0, 95% CI, .7-1.4, fair health 1.4; CI .9-1.9, poor health 1.3; CI, .7-2.1), and a history of low back pain (RR, 1.7; 95% CI, 1.3-2.1) were independent risk factors for developing neck pain.³²

Psychological status was found as one risk factor for neck pain and was further examined in a longitudinal study in which researchers considered poor psychological status during adolescence (ages 15 to 18 years) as a predictive risk factor for neck pain in young adulthood (ages 22 to 25 years).³³ The study was conducted by issuing a psychosomatic symptom score (PSS) to randomly selected high school students (N=394) and then taking a follow-up score seven years later. Researchers analyzed PSS associated to weekly neck and shoulder pain during the past six months in adulthood. They determined that a change on the PSS as small as one unit during adolescence lead to an increased risk of neck pain in early adulthood [Odds Ratio (OR) 1.0; 95% CI, 1.0-1.1].³³ This researchers compelling evidence that neck pain in adolescence effects neck pain later in life suggests that focusing on solving neck pain at onset could prevent continued neck pain related disability later in life.

Additionally, patients with Whiplash Associated Disorders (WAD), a condition typically caused by a collision resulting in soft tissue whiplash injury, are a population at risk for neck pain.² The incidence of WAD is reported to be as high as 677 per 100,000 habitants and of those affected, 30% will have symptoms for more than three months.² Risk factors of neck pain, such as WAD, can be useful in determining valuable treatment protocols. It is important to understand

that age, a smoking history, and presence of other comorbidities such as low back pain or psychological issues are all possible predictors of current or future neck pain.

2.1.3.2. Forward Head Posture

Forward Head Posture (FHP) is the most prevalent abnormal posture in people with neck pain and therefore one of the greatest predictors of neck pain.³⁴ FHP is defined as a forward projection of the head relative to the trunk in the sagittal plane and is classified by three levels of severity; slight, moderate, or severe.³⁵ The anatomical changes caused by FHP add increased biomechanical stress on the cervical spine resulting in musculoskeletal disorders such as headache, cervical pain, temporomandibular and muscular dysfunctions.¹⁰ The muscles most commonly involved in forward head posture are sternocleidomastoid (SCM), rectus capitis posterior (RCP), oblique capitis superior (OCS), semispinalis capitis (SSC), and longus coli (LCo).³⁵ The biomechanical changes of FHP cause a permanent contraction of the dorsal cervical muscles due to the induced flexor torque.³⁵ In fact, in a study where researchers compared cervical muscle thickness between women with and without FHP (N=70), researchers found through diagnostic ultrasound the SCM muscle showed significant increase in thickness in women with FHP compared to their matched controls (M = .7mm; 95% CI .14, 1.25mm; p=.014).³⁵ For the purposes of this study, FHP was defined as having a craniovertebral angle (CVA) greater than 48 degrees. Also notable but not significant, was the increased thickness of the RCP muscle in FHP subjects (M=.81mm; p=.07) compared to non-FHP participants (M=.59mm).³⁵ The researchers hypothesized that a thicker SCM muscle in patients was FHP is attributed to disuse of the deep cervical flexor muscles (DCF) leading to dominance of the superficial neck flexors such as the SCM and tonic contraction of the SCM muscle caused by the increased craniovertebral angle (CVA).³⁵ Also in support of their hypothesis, researchers found

that the LCo muscle was less thick in FHP participants ($M=1.1\text{mm}$) compared to controls ($M=.9\text{mm}$) potentially due to disuse of the DCF muscles in sitting posture when forward head translation is present.³⁵ However, the variation in LCo thickness was not statistically significant ($p=.53$).³⁵ Therefore, one potential treatment option is producing increased muscle firing in the DCF muscles and relaxation of the SCM through electrical stimulation or Kinesio® Tape.

In a similar causal-comparative study, researchers examined the thickness of cervical neck extensor muscles involved in cervical neck pain with diagnostic ultrasound. Performed on a group of female volunteers, 15 with chronic neck pain and 15 without neck pain, it was found that patients with chronic neck pain had smaller, less developed, cervical multifidus muscles ($p=.03$) and smaller semispinalis cervicis muscles ($p=.01$) via diagnostic ultrasound diagnosis.³⁶ This research was only performed on a small sample size of females, so it lacks in generalizability; however, this further explains the anatomical impacts of FHP on the cervical musculature and the need for guided and muscular specific interventions.

In order to further examine a causal relationship between neck pain and inactivity of cervical extensor muscles, a group of researchers examined induced neck pain on muscle contraction via muscle functional magnetic resonance imaging (mfMRI).³⁷ Baseline images were taken on 15 healthy individuals (7 male and 8 female; mean age 24.0 ± 3.2 years) with no history of neck pain or pathology. Following baseline data collection, the participants performed a cervical extension task at 20% of their maximal effort consisting of three, 1-minute repetitions and 15-second rest periods. MfMRI was performed again to view muscle activity. After the control condition was complete, each participant had neck pain induced. In order to induce pain, a bolus of hypertonic saline (0.5 mL; 5%) was injected into the upper division of the trapezius muscle on the right side at the midpoint between the spinous process of C7 and the acromion.³⁷

Once the participant reported pain on a numerical rating scale of at least 4/10, the performance of the extension task was commenced immediately followed by an additional mfMRI.

The researchers compared mfMRI data for the cervical multifidus, semispinalis cervicis, splenius capitis, and semispinalis capitis muscles between the pain and non-pain conditions. In the pain condition, the activity of the cervical multifidus and semispinalis cervicis muscles were reduced bilaterally at the C7 to T1 vertebral level ($P=0.045$).³⁷ Additionally, the splenius capitis muscle in the presence of pain experienced a significant reduction in activity at C7 to T1 on the side of injection and heightened activation on the side contralateral to the injection (C2 to C3 $P=0.008$, C7 to T1 $P=0.055$).³⁷ No significant changes were observed for the semispinalis cervicis muscles.

Based on the findings presented in this study, there is a decrease in cervical extensor muscle activity (cervical multifidus, semispinalis cervicis, and splenius capitis) during the performance of a cervical extension task in response to experimentally-induced muscle pain.³⁷ Even though there was a small sample size and no placebo group, the evidence suggests deficiencies in the strength and endurance of cervical extensor muscles in patients with neck pain.³⁷

2.1.3.3. Mask Wearing

The required usage of masks during the COVID-19 pandemic to decrease disease transmission has created a question as to the effects of mask-wearing on neck pain.¹¹ Due to the novelty of the virus and widespread personal protective equipment (PPE) usage, research is scarce on information of how masks may effect neck posture and facial pressure. A recently published study provided insight into how PPE is affecting healthcare workers.¹¹ Masks, a common form of PPE, are worn by most healthcare workers while on the job. In Singapore,

researchers examined how the use of PPE, defined as an N95 mask and goggles, over a 30-day period, effected new onset headaches in healthcare workers at a major hospital.¹¹ Through a self-administered questionnaire, they collected information on demographics, past medical history of headaches, and PPE patterns, including duration of use and type of PPE. Data were collected on 158 healthcare workers, majority female between the ages of 21-35. On average, respondents documented wearing the N95 face mask for 18.3 days over the 30-day study, with average time of 5.9 hours per day. Researchers found when wearing the N95 mask, 53.1% of participants reported headaches as “likely” and majority (82.8%) reported that PPE-associated headaches resulted in a “slight decrease” in work performance.¹¹ Participants with pre-existing primary headache diagnosis or emergency department personnel were most likely to develop new PPE-associated headaches (OR = 3.44, 95% CI 1.14-10.32; P = .013 and OR = 2.39, 95% CI 1.05-5.47; P = .019, respectively).¹¹ Researchers were able to identify PPE usage patterns to determine that wearing an N95 mask for more than four hours a day or more than 15 days a month resulted in the highest risk for headache development (OR = 1.59, 95% CI 1.15-2.18; P < .001 and OR = 1.34, 95% CI 0.96-1.86; P = .043, respectively). Time to onset of headache after putting on the N95 mask was observed at less than 60 minutes for the majority of participants (83%) and similarly within 60 minutes of mask removal majority of participants reported headache resolution (95.3%).¹¹ However, COVID-19 has created many other workplace factors that could lead to headaches, such as sleep deprivation, physical and emotional stress, irregular meal-times and inadequate hydration. Little research exists on how mask wearing effects the head and neck posture as well as if it contributes to headaches. Yet, descriptive statistics revealed that 23.4% of the participants reported nausea and/or vomiting, photophobia, phonophobia, neck discomfort, and movement sensitivity associated with mask-wearing.

In this study, researchers describe a strong relationship between PPE, specifically the N95 mask, and headaches in healthcare workers. The researchers presented two hypotheses for why this relationship exists: (1) pressure or tractional forces from the mask or straps on local tissue damaging underlying superficial sensory nerves such as the trigeminal or occipital nerve branches, or (2) cervical neck strain from donning the equipment could have led to the development of cervicogenic headache or tension-type headache.¹¹ Based on the information presented and current disease progression, mask wearing should be considered as a cause or contributor to headaches and neck pain.

2.1.4. Measurement

2.1.4.1. Numerical Pain Rating Scale (NPRS)

The NPRS is often used in research to characterize pain intensity due its strong psychometric properties. It is similar to the visual analogue scale (VAS), but is segmented so the respondent can only select an integer.²³ Commonly presented as a horizontal bar, it is a single 11-point numeric scale with 0 representing “no pain” and 10 representing “worst pain imaginable.”^{2,23} It is useful for many applications taking less than one minute to complete.²³

In patients with rheumatoid arthritis and chronic pain, the NPRS has been validated for reliability, validity, and responsiveness.^{21,23} The NPRS has high test–retest reliability ($r = 0.96$ and 0.95 , respectively) as well as construct validity.^{21,23} Additionally, when the construct validity of the NPRS was compared with the visual analogue scale (VAS), strong correlations were found ($r = 0.86$ to 0.95).^{21,23} The responsiveness of the NPRS has been validated in multiple studies and the common minimal detectable change (MDC) reported is two-points, regardless of baseline pain.^{23,24} To elaborate, in low back pain patients ($N=131$) undergoing outpatient rehabilitation over a four-week period, the MDC was 2 points based on comparison with the physical

therapist's perceived patient improvement and by using the 15-point Global Rating of Change scale.²⁴

Also useful in the clinical field to objectify patient progression, a minimal clinically important difference (MCID) score of two-points for the NPRS was found in shoulder pain patients.²² During a single-group repeated measures design study, the NPRS was used for both post-surgical and non-surgical shoulder pain patients (N=136) at an outpatient rehabilitation clinic. The MDIC was calculated through comparison to the Penn Shoulder Score.²²

2.1.4.2. Neck Disability Index (NDI)

Multiple quantitative and qualitative measurements exist to measure neck pain. The NDI is the most commonly used questionnaire for neck pain having been cited in over 350 scientific articles and used in over 100 treatment studies.¹⁹ The NDI is used in research to determine the extent of problems associated with neck pain. The ten-question, patient-reported outcome examines self-reported neck pain disability in relation to personal care, lifting, reading, headaches, concentration, work, driving, sleep, and recreation. A score out of 100, expressed as a percentage, is calculated from the questionnaire with a higher score correlating to greater overall perceived patient disability. Each question has five response options with correlating numbers from zero (no disability) to five. The score from each question is added together then multiplied by two. A 5-10% change in score is considered to be “minimally clinically significant”.¹⁹ The NDI has been proven to be a dependable measurement tool for neck disability and pain.

The NDI has been tested for both validity and reliability to determine its most useful and valid application. A cross-sectional study examining NDI responses of 237 neck pain patients allowed researchers to confirm the NDI has no response set bias, meaning that patients are answering the questions based on the questionnaire content, not format of the questions.³⁸ The

researchers also found that each question contributes equal weight to the final disability score and relates positively to the visual analogue scale measure of pain.³⁸ Equally important to clinicians using the NDI is its high level of internal consistency and high stability for test-retest reliability.³⁸ Overall, the assessment of patients with neck pain for disability and treatment response over time can be accurately performed using the NDI based on its stable psychometric characteristics.

2.1.4.3. Active Cervical Range of Motion

Quantitative values for ACROM are commonly measured for cervical flexion, cervical extension, left lateral flexion, right lateral flexion, right rotation, and left rotation. When quantifying ACROM, age and neck disability must be considered since it is negatively correlated to ACROM.³⁹ A cohort study examining ACROM by use of a cervical range of motion (CROM) goniometer, allowed researchers to provide practitioners with a table of typical ACROM values based on age for asymptomatic individuals when measured while seated with both feet flat on the ground and arms relaxed on the thighs.⁴⁰ The table provided illustrates the findings from the study.

Table 1. Normal ACROM and SD in Degrees Stratified for Age (N=39)⁴⁰

Age/Movement	20-29yr	30-39yr	40-49yr	50-59yr
Flexion	60 ± 10.92	58 ± 8.71	59 ± 8.40	53 ± 9.27
Extension	75 ± 10.34	69 ± 10.35	66 ± 9.71	64 ± 10.30
Side flexion left	46 ± 7.5	43 ± 6.41	41 ± 7.74	38 ± 7.98
Side flexion right	45 ± 7.46	42 ± 7.10	40 ± 8.38	38 ± 8.06
Rotation left	78 ± 7.97	79 ± 8.89	79 ± 9.31	71 ± 9.24
Rotation right	79 ± 6.63	79 ± 8.60	78 ± 9.69	71 ± 8.29

It is important to note that researchers in the cohort study found no effect of gender on ACROM.⁴⁰ This study provided relevant and quantitative ACROM values for asymptomatic patients that can be applied in the clinical setting.

In a second study, researchers found similar normative values for ACROM.⁴¹ The observational study was performed with the objective to find normal values for ACROM associated with age and sex.⁴¹ The researchers in this study also quantified ACROM with a CROM goniometer on asymptomatic volunteers from one local community (N=337). However, they collected the data and were not blinded to the results, so there was potential for bias. Similar to the previous study, ACROM was measured with the subject seated, feet flat on the floor and arms relaxed at the subject's sides. As stated above, the researchers found a negative correlation between ACROM and age. In addition to age, the results from this study indicate that females have greater ACROM in all age groups and directions except flexion.⁴¹ A condensed version of the results can be found in table below.

Table 2. Normal Mean (in degrees) and SD for ACROM by age (N=337)⁴¹

	11-19 (n=40)	20-29 (n=42)	30-39 (n=41)	40-49 (n=42)	50-59 (n=40)	60-69 (n=40)	70-79 (n=40)	80-89 (n=38)	90-97 (n=14)
Flexion	64.0± 8.6	54.3± 8.8	47.3± 9.5	49.5± 11.4	45.5± 9.1	41.0± 8.4	39.2± 8.8	40.4± 8.7	36.4± 9.8
Extension	85.6±11.5	76.7±12.8	62.2±12.8	62.5±12.2	59.9±10.4	57.4±10.5	53.7±14.4	49.4±11.5	52.3±17.2
Males									
Extension Females	84.0±14.9	85.6±10.6	78.0±13.8	77.5±13.2	65.3±16.0	65. 2± 13.3	54.8±10.2	50.3±14.5	54.5±18.1
Left Rotation	72.3± 7.0	69.2± 7.0	65.4± 9.1	62.0± 7.6	58.0± 8.8	56.6± 6.7	49.7± 8.8	46.8± 9.2	45.2±16.8
Males									
Left Rotation Females	70.5± 9.8	71.6± 5.7	65.9± 8.1	64.0± 7.9	62.8± 8.4	59.7±9.1	50.1± 7.9	50.5± 10.7	53.5± 7.5
Right Rotation	74.1± 7.6	69.6± 6.1	67.1± 7.4	64.6± 9.6	61.0± 7.7	53.6± 7.4	50.0±10.2	46.4± 8.2	44.2±14.3
Males									
Right Rotation Females	74.9± 9.8	74.6± 5.9	71.7± 5.7	70.2± 6.6	61.2± 8.6	65.2± 9.7	53.4± 8.8	53.6± 10.5	51.8± 8.7
Left Lateral Flexion	46.3± 6.7	41.4± 7.1	41.2± 10.3	35.6± 8.0	34.9± 6.6	30.4± 4.7	25.0± 8.4	23.5± 6.8	22.0± 6.6
Males									
Left Lateral Flexion Females	46.6± 7.3	42.8± 4.6	43.6± 7.9	40.8± 9.3	35.1± 6.0	34.4± 8.1	26.9± 6.7	22.6± 7.1	26.6± 8.1
Right Lateral Flexion Males	44.8± 7.7	44.9±7.2	42.9± 8.5	30.0±10.9	35.6± 5.4	29.8± 5.4	25.8± 7.3	23.8± 6.2	22.2± 9.1
Right Lateral Flexion Females	48.9± 7.1	46.2± 6.7	46.5± 8.4	42.5± 9.2	37.3± 6.8	32.7± 9.6	27.7± 7.3	26.3± 5.7	22.6± 7.2

While this study provided valuable information on normal values for ACROM and the relationship between age and ACROM, the more recent study discussed above by Swinkels et al. (2014), is arguably more relevant for clinical application today based on its more recent existence and use of a potentially updated measurement tool.

Active cervical range of motion (ACROM) is used frequently in both research and clinical settings to quantify patient injury, recovery and disability related to neck pain. The association between ACROM and neck disability was documented by a single group repeated measures design study, in which researchers examined ACROM on patients (N=30) with neck pain and an NDI score of less than 60%.⁸ The researchers excluded patients with an NDI score greater than 60%, reasoning that those with high neck disability may experience significant symptom exacerbation with repeated ACROM movement.⁸ A gravity goniometer was utilized to quantify ACROM in flexion, extension, rotation in full flexion, and lateral bending. Through experimentation, the researchers recorded an association between ACROM and neck disability in the sagittal plane (flexion + extension) ($r=.43$) and the total transverse plane (left rotation + right rotation) ($r=.40$).⁸ While this study provided thoughtful information on the importance of measuring sagittal and transverse ACROM to treat and evaluate neck disability, there were limitations with the study. The researchers chose to use a gravity goniometer to measure ACROM, which is clinically relevant and reliable, but not the gold standard for measurement of ACROM. Also, the study only had 30 participants, but the participants examined had diagnosed neck disability which strengthens the application of the research results. Although this study is not without limitations, the researchers confirmed ACROM can be used to determine disability and track patient recovery in individuals with neck pain.

In a similar repeated measures design study, other researchers supported the association between ACROM, NDI scores, and neck pain with similar documented findings. In this study, neck pain patients with NDI scores greater than five ($n=19$, $M_{\text{NDI}}=14.4\pm7.3$) were compared to healthy controls ($n=20$, $M_{\text{NDI}}=.6\pm 1.2$).⁴² ACROM was measured using a gravity inclinometer and taken with the patient seated for cervical flexion, extension, and side bending and with the patient supine for cervical rotation. The researchers analyzed the efficacy of using the gravity inclinometer and found it to have moderate to almost perfect intra-rater and inter-rater reliability depending on the motion being measured.⁴² However, this measurement tool is not the gold standard for ACROM measurement, which is radiographic imaging. Researchers found that ACROM was significantly less in patients with neck pain for flexion ($p<.001$), extension ($p=.007$), left side bend ($p=.012$), right rotation ($p<.001$), and left rotation ($p<.001$).⁴² There was no significant decrease found for right side bend motion ($p=.511$), which could have been due to right-hand dominance in participants although this variable was not examined in the study.⁴² This evidence suggests that practitioners should consider using ACROM to determine overall patient improvement and prognosis in individuals with neck pain.

Age is an important variable to consider when assessing ACROM. Researchers have concluded through a systematic review of seven studies examining the relationship between age and ACROM that multiple neck motions significantly decrease with age. Specifically, flexion decreases from the 20s to the 30s ($M= 4.6^{\circ}\pm 2.96^{\circ}$; $p=.002$) and from the 40s to the 50s ($M= 3.25^{\circ}\pm 2.21^{\circ}$; $p=.004$), and from the 20s to the 60s extension decreases ($M= 21.67^{\circ}\pm 11.88^{\circ}$; $p=.0004$) in addition to lateral side bending on both sides ($M= 13.31^{\circ}\pm 5.81^{\circ}$; $p=<.0001$). Also of significance, the researchers found that axial rotation decreased continuously from the 30s to the 60s to the left ($M= 11.94^{\circ}\pm 3.37^{\circ}$; $p<.0001$) and the right ($M= 11.74^{\circ}\pm 1.95^{\circ}$; $p<.0001$).³⁹

Acknowledging that typical values for each direction of cervical range of motion decrease with age can assist practitioners in diagnosing and treating neck pain.

2.1.4.2.1. Universal Goniometer

A simple and affordable method of measuring ACROM is by use of a universal goniometer (UG). The UG is a tool used to measure range of motion at any joint in the body and can also be used to measure all cardinal planes at the cervical spine. Motion measurement at the cervical spine must be done with the patient seated and their arms relaxed at their sides to avoid extravagated movement caused by the addition of shoulder or back motion. One limitation of the UG is the landmarks the practitioner uses to measure ACROM, which include the external auditory meatus, spinous process of C7, and the cranial aspect of head. Landmark palpation at the cervical spine is challenging and increases the likelihood of measurement error.⁴³ Due to the complexity of ACROM measurement in the cervical spine, the UG is most accurate when used with a fixed landmark, such as glasses, and with specific patient position protocols.⁴³ The UG has been used in multiple research studies with the purpose of examining ACROM based on its reliability and accessibility.⁴³⁻⁴⁵

A double-blind interrater and intra-rater reliability study design examined the use of the UG to measure ACROM accurately.⁴⁴ Researchers enlisted two physiotherapists with eight years of experience to measure each direction of ACROM with a UG on healthy individuals with no history of neck pain (N=19, n_{male}=10, n_{female}=9). The participants were blinded to the results while the physiotherapists were blinded to each other's results. The researchers indicated the use of the UG for ACROM measurement based on strong findings for interrater (ICC .79-.92 varying between directions), between-session intra-rater (ICC .79 to .97 varying between directions), and within-session interrater (ICC .83-.98 varying by direction) reliability.⁴⁴ While the results of this

study support the use of the UG for measurement of ACROM, it lacks in generalizability as it was performed on a small age range ($M_{age}=21.32 \pm 1.29$ years) and only on participants with no history of neck pain.

In a second, comparable study performed on a larger population of participants with no neck pain ($N=100$, $n_{male}=50$, $n_{female}=50$; $R_{Age}=18$ to 84 years; $M_{age}=32$ years), researchers compared visual estimation, the UG, and the cervical range of motion (CROM) goniometer to radiographic assessment of ACROM. Five orthopedic surgeons performed the visual estimation of cervical range of motion and two researchers collected data on range of motion using the UG and CROM goniometer. The researchers found that visual estimation was neither reliable nor accurate when compared to the CROM goniometer or the UG.⁴³ They also found that the UG had high interobserver reliability in all directions of motion. However, when the CROM goniometer and UG were compared against each other, the CROM device was found to be superior to the UG. The table below summarizes the study results.

Table 3. Interobserver Reliability for CROM Goniometer, UG and Visual Estimation ($N=100$)⁴³

Movement	CROM	UG	VE
Flexion	.93	.78	.88
Extension	.93	.83	.80
Right Lateral Flexion	.66	.83	.89
Left Lateral Flexion	.80	.77	.90
Right Rotation	.67	.84	.88
Left Rotation	.82	.87	.86

Based on these findings, the UG is valid when used in a clinical setting; however, as in aforementioned experiment, this study lacks clinical relevancy because it was performed on participants without neck pain. The researchers' findings also indicated that the UG was inferior to the CROM device in reliability.

To determine which measurement device is best suited to measure ACROM in symptomatic patients, researchers conducted a correlational study on patients with neck disability.⁴⁵ Eleven physical therapists measured ACROM with the UG and CROM device on a convenience sample of participants referred with neck pain and neck disorders ($N=60$, $n_{\text{males}}=21$, $n_{\text{females}}=39$) of varying ages ($M_{\text{age}}=59.1 \pm 15.7$ years; $R_{\text{age}}=21-84$ years).⁴⁵ Similar to previous studies, researchers calculated intraclass correlation coefficients and found high intra-observer reliability for the UG (flexion ICC=.86, extension ICC=.83) and the CROM device (flexion ICC=.95, extension ICC=.90). Also pertinent, researchers found the CROM device had higher interrater reliability (ICC=.73-.92 varying between directions) compared to the UG (ICC=.57-.79 varying between directions).⁴⁵ It should be noted that in this study, participants were all volunteers from one clinic, and therefore the results of this study lack generalizability to a larger population.

Based on the current research,⁴³⁻⁴⁵ the UG has excellent reliability, but has not been proven as superior to the CROM device in assessing ACROM. The UG has clinical applicability based its high accessibility as a result of low cost and ease of application. However, clinicians should consider the use of the CROM device over the UG when striving to achieve the highest accuracy.

2.1.4.2.2. CROM Device

The CROM device, or CROM goniometer, is a tool often used in research and the clinical setting to take ACROM measurements as an indicator for cervical dysfunction and a contributor to neck pain. The device is composed of a plastic frame, which is secured on the head over the nose and ears by Velcro straps. Three separate inclinometers in the sagittal, horizontal, and frontal planes capture head position with movement. The device provides sophisticated motion

analysis with quick and easy application. It has less measurement error in clinical application due to minimal landmark palpation requirements. The low cost, typically under \$1000, make it an affordable tool suited for clinical application. The CROM device is considered valid and reliable for quantifying neck movement regarding injury, recovery, and disability. In a systematic review (N=33 studies), researchers named the CROM device and the EDI-320, which is a digital inclinometer device, best in clinometric aspects such as reproducibility, validity and responsiveness.⁴⁶ Also, the CROM was named as most appropriate instrument for the assessment of ACROM in patients with non-specific neck pain based on clinical acceptability.⁴⁶

The CROM device has strong validity when compared with the gold standard of measurement for ACROM, radiographic imaging.⁴⁷ In order to validate the CROM device, researchers recruited a convenience sample of health services faculty at one university with no history of cervical pain within three months (N=31, n_{male}=10, n_{female}=21, R_{age}=18-45 years).⁴⁷ Three physical therapists gathered ACROM measurements on the participants in cervical flexion and extension. Radiographic imaging immediately followed measurements taken with the CROM device. Researchers performed the Pearson product-moment correlation for the CROM device versus the radiographic method and found strong correlations with both flexion ($r=.97$, $p<.001$) and extension ($r=.98$, $p<.001$).⁴⁷ Additionally, they discovered high interrater reliability for both flexion and extension with the CROM device (ICC=.99).⁴⁷ However, this study lacks generalizability based on its homogeneous sample and collection solely on healthy individuals. Also, the researchers only examined cervical flexion and extension because they had to limit participant radiation to three radiographs to satisfy IRB recommendations. Despite the limitations of this study, the strong evidence from this research supports the validity of the CROM device for the measurement of ACROM.

A quasi-experimental design study with a one-group comparison provided similar results to the previous study supporting the reliability of the CROM device for the measurement of ACROM.⁴⁸ Additionally, the researchers collected information on the minimal detectable change (MDC) of ACROM when using the CROM device.⁴⁸ The study was performed on healthy adult volunteers from one rehabilitation center (N=20, n_{male}=9, n_{female}=11; M_{age}=37 ± 15 years). Researchers examined all six directions of cervical range of motion with the CROM device compared to the validated Fastrak electromagnetic three-dimensional system. Pearson product-moment correlation coefficients revealed strong relationships between the two systems (r=.93 to .98 varying by direction), suggesting the CROM device had high validity for measurement of ACROM. Researchers also confirmed excellent test-retest reliability for the CROM device (ICC=.89-.98 varying by direction). Based on the data collected from this study, an MDC was established for ACROM. A change of more than 6.5 degrees in any direction indicates a true change.⁴⁸ In some directions, such as right side flexion, a change of only 3.6 degrees is clinically significant.⁴⁸ The results of this study validate the use of the CROM device in the clinical setting in order to document baseline neck disability and treatment effectiveness in comparison to reliable three-dimensional (3D) motion analysis.

2.1.4.2.3. Three-dimensional (3D) Motion Analysis of ACROM

Motion analysis software systems have strong psychometric properties, making them appropriate instruments for use in research and the clinical field. While they are more costly and require research laboratories and trained personnel for use in comparison to the CROM device, they can contribute to the quality of a research study. In 3D motion analysis, two non-invasive sensors are attached to the individual, one in the lower cervical or upper thoracic region of the

spine and the other on the forehead in line with the bridge of the nose. Active motion is recorded and analyzed to quantify quality of motion with calculated measurements.

Researchers performed a study to illustrate that 3D motion analysis with Fastrak software could measure cervical flexion and rotation with little error and strong replicability.⁴⁹ Participants (N=15) were seated in a fixed back chair and motion sensor chips were placed as follows: (1) on a semi-rigid plastic headband on the forehead in line with the bridge of the nose and (2) the seventh cervical vertebrae (C7) with double-sided tape. From a neutral position, they were asked to flex the neck, then rotate to either side. Data was collected three times for each motion on two separate testing days. It should be noted participants were excluded if they experienced regular headaches or had received treatment for shoulder or neck pathologies within the last three months. Standard errors of the means (SEM) and interclass correlational coefficients (ICC) indicated good to excellent repeatability within and between days for flexion and right/left rotation (range of ICC values 0.85–0.95; SEM 1.4-2.01°).⁴⁹ Based on this data, researchers concluded that 3D motion analysis with Fastrak software had excellent replicability and little error.

Using the previous study as a reference, another group of researchers examined the reliability and validity of the CROM device in comparison to 3D motion analysis using Fastrak software.⁴⁸ ACROM was measured in extension, bilateral rotations, flexion and bilateral side flexions with the patient seated in fixed back chair (N=29). Sensors were placed on the forehead and at the sixth thoracic vertebrae, which deviates from the procedure utilized in the aforementioned study. Researchers collected data in two sessions on each participant, 48 hours apart. They found the following correlation coefficients between the CROM device and 3D motion analysis: 0.98 for extension and bilateral rotations, 0.93 for flexion, and 0.96 to 0.97 for

bilateral flexions.⁴⁸ However, this experiment was performed on healthy, asymptomatic adults which limits its potential application to the clinical field.

The sophistication and strong psychometric properties of 3D motion analysis validate its use in research despite its downfalls such as cost, lack of mobility, and required training compared to the inclinometer, goniometer, and CROM device.^{48,49} It is a safer alternative to the “gold standard” for range of motion measurement, which is radiographic imaging, due to the lack of exposure to radiation.

2.1.4.2.4. Radiographic Imaging of ACROM

Radiographic imaging is considered the “gold standard” for quantitative measurement of ACROM.^{42,43,47,50,51} It is commonly used as a reference device for concurrent evaluation of validity for other measurement tools. However, research is lacking on the reliability and validity of radiographic imaging for neck pain due to the restrictions accompanying it.⁵¹ Radiographic machines are expensive to purchase and operate and limit study population based on potential side effects of radiation from imaging. The Federal Drug Administration (FDA) advises against excessive or unnecessary use of radiographic imaging. One specific risk associated with radiographic imaging is cancer development later in life.⁵² The FDA recommends special consideration of radiographic imaging on pediatric patients because of increasing sensitivity to radiation, pregnant women because of potential harmful effect to the fetus, and on women because they are at a higher risk for radiation-associated cancer than males.⁵² Also, radiographic imaging requires special facilities and qualified operators to obtain and analyze the images.⁴³ The barriers related to radiographic imaging make it a less common procedure to determine ACROM. Therefore, other devices are often used to measure ACROM, such as the CROM device, because it is a cheaper and safer alternative to determine diagnosis and treatment progress.⁴⁶

Although riskier and more expensive, researchers have attempted to demonstrate radiographic imaging is superior to other ACROM measurement devices. A comparison between radiographic imaging, the bubble goniometer, and the dual inclinometer was preformed examining ACROM results. After recruiting staff and students from one college campus (N=115, n_{males}=66, n_{female}=39, R_{age}=29-64 years), researchers collected data and ran paired *t*-test to determine that radiographic imaging yielded significantly different range of motion measurements than the bubble goniometer and dual inclinometer (p=.01). Researchers determined radiographic imaging had higher sensitivity for measurement of ACROM than the two alternative devices tested. Based on these findings, the authors concluded that radiographic imaging provided a more accurate evaluation of ACROM.⁵⁰

Overall, radiographic imaging remains an option to quantify ACROM, especially in the clinic or hospital. However, for physical therapists, chiropractors, and other health care providers, focusing on neck pain treatment, alternative cheaper and less invasive devices exhibit greater relevance. The UG or CROM device should be considered for clinical application with the latter option as a more accurate ACROM assessment tool.

2.1.4.4. Forward Head Posture

Forward head posture (FHP), defined as upper cervical extension and lower cervical flexion, is often used as an objective measurement of neck pain and is typically targeted as a treatment for neck disability.¹⁵ The constant stress caused by an increased load on the cervical extensor muscles in individuals with FHP leads to neck pain.¹⁵ While it is possible to identify FHP visually, quantitative angle measurements provide more accurate information and can lead to superior diagnosis and treatment. An objective measurement of FHP can be found by using the cranio-vertebral angle (CVA), calculated between a horizontal line through the spinous process

of C7 and a line from the spinous process of C7 through the tragus of the ear.⁵³ The clinical definition for FHP in relation to CVA varies between literature. However, the most common measurement provided in literature to define FHP is a CVA angle of less than 50 degrees.^{10,54,55} CVA can be measured by use of a goniometer, photogrammetric quantification, or radiographic imaging.

Goniometer assessment of CVA is a quick and useful measurement to gather in a clinical setting. The accuracy of goniometer assessment of CVA has been tested in comparison to other CVA measurement techniques, such as programmatic quantification. In a literature review of 21 studies, researchers examined various postural angles and the measurement techniques for these angles to determine their most useful application.⁵⁴ The researchers discovered that goniometer measurement of CVA had poor to moderate interrater reliability (ICC=.68), whereas photogrammetric quantification had moderate to high interrater reliability.⁵⁴ Radiographic imaging is considered the “gold standard” for its reliability but exposed patients to harmful radiation and required expensive equipment and trained radiologists. Based on study results, researchers determined goniometer assessment of CVA was inferior to programmatic quantification. Additionally, the authors stated that photogrammetry of CVA provided objective and reproducible results on position of head relative to neck and was well suited for clinical application.⁵⁴

Photogrammetric quantification of FHP allows for affordable and accurate calculation of the CVA. CVA data was collected and compared between two physical therapists at one local clinic each with five years of clinical experience in a test-retest study on college students (N=45; n_{male}=20, n_{female}=25).⁵⁶ FHP was defined in this study as a CVA of less than 54 degrees and was measured in the sagittal plane while the participant was seated. Three meters was placed between

the subject and the camera. CVA was calculated using the PWAS statistical package for Windows.⁵⁶ Photogrammetric assessment of the CVA was found to have a high intra-rater reliability (ICC= .91) and high inter-rater reliability (ICC=.75).⁵⁶ However, this study had several limitations. A typical distance of camera placement to patient is cited as 1.5 meters in other literature.^{10,57} Positioning the camera at a greater distance may have effected data accuracy. Also, the results of the study can only be applied to college students without neck pain. Despite the stated limitations, the data collected from this study allowed researchers to determine that FHP can be measured reliably using photogrammetric assessment of the CVA.

In addition to adults, photogrammetric quantification has been tested for reliability and validity in adolescents. The purpose of the study was to investigate the interrater and intra-rater reliability of photographic posture analysis.⁵⁷ The researchers examined five postural angles on adolescents (N=30; n_{male}=15; n_{female}=15; M_{age}= 16.4 ± 0.4 years) utilizing photographs with angle analysis on MB-ruler software (Markus Bader- MB Software Solutions), whereas the aforementioned study used PWAS for angle analysis. The angles measured included the CVA, cranio-horizontal angle, trunk angle, lumbar angle, and sway angle. Each angle was measured on each participant by two examiners separately and then repeated one week later. Calculations for interclass correlation coefficients revealed high interrater reliability (ICC .77-.99 varying between angles) and high test-retest reliability (ICC .97-.99 varying between angles).⁵⁷ Relevant to this literature review, researchers found excellent interrater reliability (ICC=.98) and test-retest reliability (ICC=.93) for the CVA specifically.⁵⁷ The conclusions of this study can only be applied to adolescents aged 16 to 17 years. Nevertheless, the results of this study provide promising evidence for the use of CVA photogrammetric quantification as a non-invasive diagnostic technique and treatment progression tool for neck pain in adolescent patients.⁵⁷

In further support that CVA is a valid and reliable measurement for FHP, researchers gathered a convenience sample of 78 female volunteers ($M_{\text{age}} = 23 \pm 2.63$ years) classified with FHP to compare with CVA, head tilt angle and head position angle.¹⁰ The digital imaging techniques to evaluate cervical angles were similar to previous studies using the same anatomical landmarks and camera-to-patient distance of 1.5 meters. CVA was assessed using Adobe Acrobat Software. Patients were grouped based off visual FHP classification into one of three groups: non-FHP, slight FHP or moderate-severe FHP. Based on objective findings, researchers recommended photogrammetric CVA quantification as the best predictor of FHP based on excellent intra-rater reliability (ICC=.90; SEM=1.94), interrater reliability (ICC=.92; SEM=1.74), and intra-subject reliability (ICC=.89, SEM=2.04).¹⁰ Results of a Linear Discriminate Analysis showed that CVA was most accurate at discriminating severity of FHP (Wilks' lambda: .31; Canonical Correlation=.83; $p=.00$).¹⁰ Head posture angle and head posture tilt provided no significant difference between FHP groups, therefore indicating no clinical benefit for objective head posture assessment.¹⁰ However, the results from this study lack generalizability based on gender and age discrimination. Another concern with this research is the use of visual observation to classify FHP severity for group assignment. Researchers did note that CVA angle for FHP groups in this study was consistent with nominative values ($M_{\text{non-FHP}} = 55 \pm 3.3$ degrees; $M_{\text{moderate-severe}} = 41.9 \pm 3.9$ degrees; $M_{\text{slight FHP}} = 48.7 \pm 2.5$ degrees), which validated the use of visual estimation of FHP for this study. Based on the evidence gathered in this study, photogrammetric measurement of CVA can be used as an acceptable objective method for measuring FHP.¹⁰

Multiple research studies have validated photogrammetric CVA measurement as a quantitative tool for FHP delineation.^{10,54,56,57} When compared to other common tools, such as

the universal goniometer, photogrammetry is more precise and reliable. It has no known side effects and can be analyzed with simple and affordable software. Therefore, use of CVA to determine FHP diagnosis and treatment success in patients with neck disability is valid and reliable for both clinical and research application.

2.1.5. Treatment

The increasing prevalence of neck pain has created substantial disability and economic consequences worldwide. Neck pain is ranked as the fourth greatest contributor to disability globally and medical care expenditures are estimated at nearly \$86 billion a year in the United States.^{6,7} In 50% of patients with neck pain, symptoms will linger or return frequently, creating a need for treatment.⁵⁸ Common practice is to refer patients with neck pain to physical therapy for an exercise and stretching combination treatment program. In fact, 61% of patients who report to their physician for neck pain are referred to physiotherapy for treatment of their condition.⁴⁰ For that reason, researchers have been trying to identify and specify best treatments for neck pain. Possible treatments vary from cervical muscle strengthening and range of motion programs to interferential current therapy on the upper trapezius and levator scapulae. However, these treatments can be costly and require long term application before the patient feels a noticeable improvement in their condition. Promising research on the use of Kinesio® tape for immediate and long-term postural feedback, increases in range of motion, and pain relief have been demonstrated as useful in the treatment of neck disability.^{1-4,13,26}

2.1.5.1. Exercise and Motion Programs for FHP and CVA

Evidence-based practice to treat and alleviate symptoms of neck pain is to strengthen the weakened cervical muscles and stretch the shortened muscles. However, some programs only resolve symptoms, not the root cause of the problem, which is most commonly posture.¹⁶

Therefore, exercise programs with the goal of decreasing FHP and increasing CVA are more effective at decreasing patient self-reported neck pain.^{14,34} Common exercise programs for neck pain include the McKenzie program and the Kendall program; however, other individualized programs have been researched as well.

In a systematic review and meta-analysis of seven randomized-control trials, researchers examined the effect of corrective exercises on postural variables in individuals with FHP.¹⁷ Odds ratios calculated between-groups for CVA and cranial angle (CA) were provided by the researchers. Differences were observed between studies in exercises performed and intervention length with a range in duration of four to 32 weeks and between two to seven sessions per week. No significant difference was observed for CA between individuals in a corrective exercise program and those who were not.¹⁷ However, strong evidence was found for CVA improvement on participants in an exercise program (OR=6.7; CI=2.53-17.9; p=.0005).¹⁷ The mean improvement in CVA was 4.5° in participants with neck pain and 4.58° in painless participants. Additionally, moderate evidence was found for pain reduction in participants in an intervention groups (OR=.3; CI=.13-.42; p<.001).¹⁷ Overall, corrective exercises stand as an evidence-based therapeutic intervention for neck pain and posture. However, based on the differences seen in CVA and pain score changes between studies, specific exercises and length of intervention may affect patient results.

The McKenzie exercise and the Kendall exercise programs are two common treatment regimens used to treat neck pain and disability.¹⁸ The McKenzie exercise program is a self-therapy plan focused on mobilization and manipulation of the neck with an emphasis on stretch exercises. In comparison, the Kendall exercise program strengthens shoulder retraction and deep cervical flexor muscles while stretching the pectoral muscles. Both programs have been

found effective at correcting neck posture.¹⁸ In an experimental study, researchers studied which exercise program was superior at improving FHP and rounded shoulder posture (RSP). They compared the McKenzie exercise and Kendall exercise programs to a third self-stretch exercise group that combined the strengthening exercises from Kendall with the mobility exercises from McKenzie. Participants with FHP who performed no regular exercise and used a smartphone or computer for four or more hours daily were assigned to one of the three groups ($n_{\text{McKenzie}}=9$; $n_{\text{Kendall}}=9$; $n_{\text{self-stretch}}=10$). The eight-week study examined pre-test and post-test measurements of CVA and scapular index using photographic posture analysis. Each intervention lasted 25 minutes and was performed three times weekly. While the participants were randomized into groups, the exercises were self-directed, and the results were only pooled on a small sample size, which may have affected the data. The researchers concluded that CVA and scapular index were significantly different from baseline to the study conclusion in each group ($p<.05$); however, no significant difference was found between groups.¹⁸ Therefore, McKenzie exercise, Kendall exercise, and the self-stretch exercise were all equally effective at improving FHP and rounded shoulder posture.

The researchers in the previous study validated the use of McKenzie and Kendall exercises to treat FHP. In a similar, randomized-control trial, researchers examined how often to perform a McKenzie and Kendall combination exercise program to achieve maximal improvement in FHP.¹⁵ Researchers compared CVA on 32 participants ($n_{\text{female}}=15$; $n_{\text{male}}=17$; $M_{\text{age}}= 21.6 \pm 1.9$ years) at baseline and four weeks post-intervention.¹⁵ The participants were randomized into three groups based on number of times the intervention was performed; either once, twice, or three times daily. Skilled physical therapists supervised the intervention performance to ensure participants were completing the exercises properly. Through statistical

analysis researchers found significant improvements in CVA in each intervention group ($p < .01$).¹⁵ However, a one-way ANOVA between-groups revealed a significant ($p < .05$) difference in CVA from performing the intervention once daily and three times daily with the latter group having greater CVA improvement.¹⁵ While the results are limited in generalizability by sample size and participant age range, the results of this study can be used to determine that a combined McKenzie and Kendall exercise program of strengthening and stretching is effective at improving FHP.¹⁵ However, performing therapeutic cervical exercises more frequently, such as three times daily, may result in greater improvement in FHP and better patient outcomes.¹⁵

Traditional McKenzie and Kendall strength and stretching programs are useful in the treatment of FHP and neck pain but may require a trained physical therapist to administer and educate the patient on how to properly perform the exercise. Pilates, a less traditional treatment for neck pain, has been studied as a possible corrective exercise treatment method for FHP.¹⁶ The physical fitness exercise system is designed to improve health and flexibility through core, posture, and coordination strengthening accompanied by specific movement breathing.¹⁶ The effect of a pilates exercise program on the treatment of FHP was examined in a randomized, controlled, double-blind study of females with FHP ($N=28$).¹⁶ Subjects were divided into the pilates intervention group ($n=14$) or a combined exercise group ($n=14$). Both groups performed the exercises three times weekly for 50 minutes each session. The pilates routine consisted of exercises to stretch the neck extensor and pectoral muscles while strengthening the deep flexor muscles, shoulder retractor muscles, back and core muscles combined with breathing techniques. The combined exercise group ($n=14$) performed traditionally prescribed stretching and strengthening exercises on the FHP-related major muscle groups. Researchers were interested in CVA change over the ten-week intervention period as well as pain, neck disability, cervical

range of motion (CROM), and cervical muscle fatigue. CVA was obtained using angle measurement from x-ray imaging. Participants were also given the neck disability index (NDI) to determine neck disability and asked to report neck pain on the visual analogue scale (VAS) both at baseline and following the ten-week intervention. CROM was measured using the CROM device and surface EMG was used to determine sternocleidomastoid (SCM), upper trapezius, and C4 paraspinal muscle fatigue on the patient's right side while sitting.

Following intervention, the pilates group experienced significant improvement in CVA ($p=.002$) and in CROM in flexion ($p=.017$), extension ($p=.037$), right rotation ($p=.034$), right lateral flexion ($p=.006$), and left rotation ($p=.045$).¹⁶ The combined exercise group experienced no notable changes in CVA or CROM. Also, a significant decrease in pain and neck disability was documented in the pilates group at the conclusion of the study ($p<.001$ both).¹⁶ Likewise, the traditional exercise group experienced a significant decrease in pain and neck disability after their ten-week intervention ($p<.001$ both).¹⁶ The only significant change reported between-groups in relation to muscle fatigue was a decrease in SCM fatigue after ten-weeks, which was documented in the pilates group ($p=.026$).¹⁶ However, it is important to note that this study was only performed on females and therefore lacks generalizability to a greater population. Researchers demonstrated that a ten-week pilates exercise program was superior to a stretching and strengthening combined exercise program for increasing CVA angle, decreasing self-reported pain and NDI scores, and decreasing fatigue of the SCM. However, while pilates appears to be superior to a traditional exercise program for improving CVA and CROM, the combined exercise program is still a viable treatment option when the goal is to decrease neck pain and overall disability.

Therapeutic exercise programs targeted at strengthening and stretching cervical and upper body musculature are common practice in the treatment of neck pain. Many types of exercises exist and are used, including Pilates, McKenzie and Kendall exercise programs, and individual strengthening and stretching combination programs. All of these programs have been found to be effective at improving FHP by changing the CVA in order to decrease patient pain and disability.^{15–18}

2.1.5.2. Kinesio Tape to treat Neck Pain

Kinesio® tape is an important area of research for its clinical application in the rehabilitation of injuries. Its specific skin-like properties are advertised to provide benefits such as tissue alignment, edema removal and increases in range of motion.²⁶ Used as an affordable and immediate therapy, Kinesio® tape can be applied to most age demographics and utilized in most clinical settings with cutaneous irritation as the only documented side effect.³ Promising research has been published on the use of Kinesio® tape to treat upper body injuries and postural abnormalities such as rounded shoulder posture (RSP) and forward head posture (FHP).^{1–4,13,26}

A prospective and randomized clinical trial examined the effect of Kinesio® tape on shoulder pain and disability in patients with diagnosed rotator cuff tendonitis (N=42).²⁶ In this double-blind study, participants were randomized into a sham taping group (n=21) or a rotator cuff tendonitis/impingement Kinesio® taping group (n=21). At baseline, shoulder ROM in abduction, forward flexion, and scapular plane elevation was measured using a traditional goniometer. Also, pain on a 100-mm visual analogue scale (VAS) and shoulder disability on the Shoulder Pain and Disability Index (SPDI) was collected. A standard rotator cuff taping procedure was utilized, using two-inch Kinesio® Tex Tape to apply a Y-strip from insertion to origin of the supraspinatus with paper-off tension. Another strip, either an I- or Y-strip,

determined by shoulder contour, was applied from the coracoid process around to the posterior deltoid for a mechanical correction defined with approximately 50% to 75% tape stretch. For this strip, the patient's shoulder was initially at their side in external rotation and then moved to flexion and slight horizontal adduction. Tape was applied for two consecutive days in three-day intervals. The dependent variables were measured at baseline, immediately post-treatment, three days post treatment and six days post-treatment. The generalization of the data collected throughout this study is limited to a young population based on the convenience sample utilized in this study ($R_{age}=18-24$ years).

Based off the collected data, researchers discovered a significant improvement in pain-free shoulder abduction immediately following tape application in the Kinesio® tape group compared to the sham tape group ($M=16.9^{\circ} \pm 23.2^{\circ}$; $P=.005$).²⁶ No significant changes were documented for pain, SPDI score or ROM at any other interval between groups.²⁶ Therefore, Kinesio® tape may be useful in improving pain-free active shoulder ROM immediately post-application but is not supported for the long-term treatment of shoulder pain or disability.²⁶ The information in this article is important to note since the experiment was performed on subjects with rotator cuff impingement while similar research in the past has been performed on healthy subjects.

The connection between the shoulder and neck in relation to posture and pain highlights the importance of researching both areas of the body. The results from the aforementioned study documented ROM improvements in shoulder disability patients. In a similar, randomized clinical trial, researchers examined the effects of Kinesio® tape on neck range of motion and disability, more specifically in comparison to another clinically accepted treatment. The researchers examined the effectiveness of Kinesio® tape versus cervical spine thrust manipulation on neck

pain, disability and CROM.³ Participants (N=80) were randomly assigned to either the Kinesio® tape or cervical spine thrust group then treated with the intervention for seven days. Baseline testing was taken for CROM with a CROM goniometer, neck disability via the NDI, and neck pain via 11-point numeric pain rating scale. A two-strip application of Kinesio® Tex tape was used on the Kinesio® tape intervention group. A Y-strip was applied with paper-off tension from the cervical extensor muscles insertion at the T1/T2 vertebral region to origin at the C1/C2 vertebral region. A second overlying strip was placed over the midcervical region (C3-C6) with the spine in cervical flexion. The tape was worn for the one-week study duration. The alternative treatment on the spine thrust group was two types of cervical thrusts directed at the mid-cervical spine and cervicothoracic junction. The researchers were able to conclude from review of the collected data that Kinesio® tape exhibited similar reductions in neck pain and disability as cervical thrust manipulation (Within group change scores: Kinesio® Tape: -2.5; CI:-2.9, -2.0); Cervical thrust manipulation: -2.3; CI: -3.0, -1.1).³ However, only the reduction of pain was statistically significant in both groups.³ Also, CROM increased in both groups in all directions, but statistical significance was only found for left and right rotation between groups with significant increases in the cervical thrust group only ($F= 7.317$, $P = .008$ for right; $F = 9.525$, $P = .003$ for left).³ It should be noted that this study had no control group, therefore there was potential for the placebo effect. Additionally, this study used a convenience sample from one clinic of patients between 18 and 55, which limits the geographical and age group generalizability to younger than 55 for the study results. Nevertheless, the results of this study validate the use of Kinesio® tape for neck pain reduction and to increase CROM through comparison to the clinically accepted treatment method of cervical spine thrust manipulation. This is promising research for an affordable, at-home neck disability treatment. Kinesio® Tape

can be applied by any individual instructed on the application, even a family member, while spinal thrust manipulation must be performed in a hospital or clinic setting by a qualified practitioner.

In another study on patients with mechanical neck dysfunction, Kinesio® tape was investigated as a supplement to common exercise programs to determine if applying Kinesio® tape can produce better patient outcomes than therapeutic exercise alone. In the randomized control trial (N=54), the researchers examined the effect of Kinesio® taping versus a cervical traction posture pump on mechanical neck dysfunction.⁴ The outcome measures examined were cervical curve lordosis via the Absolute Rotatory Angle (ARA), pain intensity on a ten-point VAS, and neck disability determined by NDI score. Participants were randomly assigned to one of three groups: (A) Kinesio® taping every four days for eight sessions with exercise program (n=19), (B) cervical traction posture pump with exercise program three days/week for 12 sessions (n=19), or (C) exercise program (n=16). The exercise program used consisted of stretching, postural and isometric exercises on the neck and shoulder three days/week for 12 sessions. For the Kinesio® taping group, two strips were applied, an I-strip and a Y-strip. The Y-strip was applied first from the T3-T5 vertebral area to the occiput of the skull with the patient in cervical flexion and no tension in the tails of the strip. Next, an I-strip was applied over the middle of the neck horizontally with the patient in cervical flexion as well, but with tension in the middle of the tape. The specific tension applied was not provided for either strip. Tape was worn for the study duration of four weeks with tape re-application every four days. The taping procedure was very similar to the one used in the aforementioned study by Saavedra-Hernández et al., with the exception of patient position during the Y-strip application, tension applied, and

length of application. Chi-square testing revealed significant post-test value differences between groups as documented in the table below.

Table 4. The Pre and Post Mean Values of ARA, VAS and NDI within Groups (N=54)⁴

Variables		Group A Mean \pm SD	Group B Mean \pm SD	Group C Mean \pm SD	Between-group differences
ARA	Pre	14.26 \pm 5.90	15.42 \pm 7.54	14.43 \pm 6.33 15.05	chi-square value = 0.712; p = 0.701
	Post	22.16 \pm 5.7	22.25 \pm 6.65	15.05 \pm 4.11	chi-square value = 11.047; p = 0.004
		<i>Pre to post difference: Z = 3.415; p = 0.001*</i>	<i>Pre to post difference: Z = 3.427; p = 0.001*</i>	<i>Pre to post difference: Z = 1.890; p = 0.059</i>	Group A and Group B higher than Group C (p = 0.002 and 0.007) respectively*
VAS	Pre	7.34 \pm 0.86	7.16 \pm 1.20	6.98 \pm 0.86	chi-square value = 0.833; p = 0.659
	Post	2.56 \pm 0.75 23.87	2.86 \pm 0.84	4.5 \pm 1.17 23.32	chi-square value = 13.880; p = 0.001*
		<i>Pre to post difference: Z = 3.461; p = 0.001*</i>	<i>Pre to post difference: Z = 3.426; p = 0.001*</i>	<i>Pre to post difference: Z = 3.475; p = 0.001*</i>	Group A & B lower than Group C: p = 0.000*
NDI	Pre	23.87 \pm 9.62	22.6 \pm 11.03	23.32 \pm 7.57	chi-square value = 0.170; p = 0.918
	Post	9.53 \pm 3.17	10.56 \pm 4.5	18.60 \pm 7.59	chi-square value = 16.301; p = 0.000*
		<i>Pre to post difference: Z = 3.416; p = 0.001*</i>	<i>Pre to post difference: Z = 3.297; p = 0.001*</i>	<i>Pre to post difference: Z = 2.932; p = 0.003*</i>	Group A and B lower than Group C (p = 0.000 and 0.002) respectively*

*= significant

In patients with mechanical neck dysfunction, the use of Kinesio® tape or a postural cervical traction pump in combination with exercise is more effective than exercise alone at reducing neck pain and disability.⁴ However, no significant difference was observed between

group A and B ($p=.884$ for ARA; $p=.673$ for VAS; $p=.466$ for NDI); therefore Kinesio® tape application is equally effective as the postural cervical traction pump.⁴ This study was performed on a small convenience sample from one clinic and the cervical Kinesio® tape application was less precise than the application in the previous study in terms of tension applied to the tape. Still, the results of this study provide evidence for the addition of Kinesio® tape to traditional exercise programs in order to significantly decrease pain and disability more than exercise alone.⁴

In a similar experimental study, researchers investigated the effects of Kinesio® taping in conjunction with traditional treatments for neck disability to determine if Kinesio® tape could improve patient outcomes when added to traditional treatments. Researchers compared McKenzie exercise, Kinesio® taping, and myofascial release (MRF) on FHP.¹³ Participants with FHP ($N=28$) were randomly assigned to one of three groups: (A) McKenzie exercise and MRF ($n=10$), (B) McKenzie exercise and Kinesio® taping ($n=9$), or (C) McKenzie exercise, MFR and Kinesio® taping ($n=9$). MRF was performed with a lacrosse ball on the upper trapezius, levator scapulae, neck extensor, and pectoralis major and minor. The Kinesio® tape application was described as two I- stripes (5 cm wide, 11 cm long) applied with participants seated with neck in a neutral position and forward gaze. The tape was applied in a “V” shape around the C7–T1 junction. This procedure is different from the previous two experiments discussed in terms of tension, patient position, and application design. Kinesio® taping was performed prior to exercise three times weekly and remained on the skin for eight hours following treatment. The interventions were performed three times per week for four weeks.

Baseline measurements and post-treatment measurements were taken via photogrammetry for CVA, the acromion and tragus of ear length (A-T length), and the cranial

rotation angle (CRA). Data analysis with repeated measures ANOVA showed significant changes in A-T length in group A ($p<.001$), group B ($p<.001$), and group C ($p<.01$) after the six-week intervention period.¹³ For CVA, only group C had a significant change over the six-week period ($p<.05$) and for CRA none of groups showed significant improvement.¹³ These results provide evidence that Kinesio® Tape combined with McKenzie exercise or myofascial muscle release decreased the severity of forward head posture in terms of A-T length; however, the best patient outcomes for decreasing the severity of FHP came when the three treatments were performed together. The generalizability of this study is limited to college students and the results were only taken on a small sample. Also, the Kinesio® tape was only applied for eight hours post-treatment, whereas in other studies it was worn constantly during the duration of the study.^{2-4,26} Similarly, there was no Kinesio® tape or exercise only group in this study, so it is difficult to determine which independent variable was affecting the dependent variables. Based on the results of the study, the researchers recommend all three types of interventions as effective treatments for FHP.¹³

Whiplash, a common cause of neck pain, is another population that has been studied with Kinesio® tape as a potential treatment for pain and to increase CROM.² In a randomized control trial, researchers investigated the short-term effects of Kinesio® Taping on neck pain and CROM. The participants (N=41) were randomly assigned to the Kinesio® Taping (n=21) or sham taping group (n=20). At baseline, neck pain was measured by an 11-point numerical pain rating scale (NPRS), in addition to neck disability by the NDI, and CROM by a CROM device. Kinesio® Tex tape was applied to both groups. The treatment group received a Y-strip over the posterior cervical extensor muscles with application from insertion (dorsal region T1-T2) to origin (upper-cervical C1-C2) and paper-off tension. The patient was seated with the neck in

cervical contralateral side-bending and rotation for each piece of the Y. Following the Y-strip, a second strip was applied perpendicular over the midcervical region (C3- C6) with the patient in cervical flexion allowing application with tension to the posterior neck structures. This application matched the application performed by Saavedra-Hernández et al. discussed previously.³ The dependent variables, neck pain and CROM, were measured again immediately post-treatment and at a 24-hour follow-up.

The group-by-time, 2-by-3 mixed-model ANOVA for the Kinesio® Tape group was statistically significant for neck pain ($F=54.8$; $p<.001$); however, the change in neck disability was not clinically significant since the change was less than two points.² Additionally, planned pairwise comparisons provided evidence that Kinesio® taping was significantly more effective at decreasing pain than sham taping ($p<.001$).² A significant change in CROM for all directions was also observed in the treatment group ($p<.001$).² The treatment group experienced statistically greater changes in CROM in all directions than the sham taping group ($p<.001$).² However, CROM only increased by a small amount which questions its significance in a clinical setting.² The results of this study provide promising evidence for the use of Kinesio® Tape as a treatment for neck pain and disability but are clouded by the small sample size and short intervention time compared to similar studies. Also, only participants with WAD were included in this study, which decreases the generalizability of the study results. Nevertheless, the researchers provided statistical evidence that Kinesio® tape can be used to decrease neck pain and improve CROM in patients with WAD. However, further research is necessary to determine if these changes are clinically significant.²

As discussed in research presented above, there is strong evidence to suggest that the use of Kinesio® Tape in conjunction with commonly used treatments for neck disability is

advantageous to the patient. However, more research is necessary on the effects of Kinesio® Tape as a single treatment for forward head posture and neck disability. To examine this relationship further, researchers performed an experimental study examining the treatment of FHP with Kinesio® tape alone on males during computer work (N=12).¹ In this study, the effect of neck retraction taping on upper trapezius activity and FHP through changes in CVA was examined. The Kinesio® Tape was applied by a trained physical therapist to both sides of the neck over the cervical extensor muscles between the C4-T7 level at 15-25% stretch. No other information was provided on the taping application. Data on CVA and upper trapezius activity was collected before taping and after 30 minutes of computer work with tape. The CVA was measured using a three-dimensional ultrasonic motion analysis system. Surface EMG on the upper trapezius muscle collected data on muscle activation.

Statistical analysis on the collected data revealed significantly decreased CVA during computer work with neck retraction Kinesio® taping compared to without ($23.0 \pm 12.5^\circ$; $p < .05$).¹ Also, upper trapezius muscle activity significantly decreased with tape compared to without ($27.1 \pm 13.5\%$; $p < .05$).¹ However, the small sample size and solely male sample utilized in this study creates generalizability challenges and the applicability of these results is limited to computer workers only. Additionally, the researchers did not provide enough detail on the taping application for it to be replicated in future studies. While these limitations exist, the results provide strong, early evidence for the use of neck retraction Kinesio® taping as a treatment for FHP.¹ More research is needed to determine the effectiveness of Kinesio® taping alone to treat FHP and neck disability.

2.1.5.3. Other Approaches to Treat Neck Pain

In addition to the treatments discussed in the paragraphs above, other approaches such as Interferential Current Therapy (ICT) and breathing exercises have been researched as treatments for neck disability. ICT is a passive therapeutic modality used to relax muscles and provide pain relief. It is hypothesized that using ICT will provide muscle relaxation similar to traditionally prescribed active stretching exercises while controlling for individual differences during treatment to provide better patient outcomes.⁵⁹ Researchers investigated ICT treatment on 30 participants to determine the effect of ICT on FHP, ear-to-acromion length distance (EAL), and posterior acromion distance (PAD).⁵⁹ Subjects were divided into a FHP group (n=15) or normal head posture group (NHP) (n=15) based on baseline NDI scores and EAL. ICT was administered with electrodes bilaterally over the upper trapezius and levator scapulae at 100 bps for 15 minutes, three times weekly for four weeks on both groups. The following results are reported from statistical analysis:

Table 5. The Effect of Interferential Current Therapy on Forward Head Posture (N=30)⁵⁹

Variable		Normal Head Posture (NHP Group) Mean \pm SD	Forward Head Posture (FHP Group) Mean \pm SD
Forward head posture (FHP)	pre	5.3 \pm 3.1 ^o	8.7 \pm 2.8 ^o
	post	3.6 \pm 2.9 ^{o*}	6.9 \pm 3.1 ^{o*}
Posterior both Acromion Distance (PAD)	pre	36.4 \pm 3.9	35.3 \pm 2.9
	post	35.93 \pm 3.9 cm*	34.8 \pm 3.0 cm*
Anterior both Acromion Distance (AAD)	pre	32.5 \pm 3.3	32.2 \pm 2.4
	post	33.0 \pm 3.4 cm*	33.8 \pm 2.5 cm*

*: significant change from pre to post at $\alpha=0.05$.

The results in the table demonstrate significant changes in the three measures of neck posture for both groups. No differences were observed between groups. Based on these results,

researchers theorized ICT worked to treat FHP by inducing relaxation of the muscles shortened during FHP which in turn decreases FHP and PAD.⁵⁹ The specific muscles they suggest targeting with ICT are the levator scapulae and upper trapezius.⁵⁹ However, this study should be replicated with a larger sample size and larger geographical area to provide results that generalize to a greater population of people.

FHP has been shown to negatively affect strength in the deep cervical flexor muscles, cause tightness in the suboccipital muscle and lead to abnormal sternocleidomastoid (SCM) and scalene muscle function.¹² While the SCM and scalene muscles are important for neck motion, they also act as accessory inspiratory muscles.¹² For this reason, breathing exercises are studied as a treatment for FHP and neck disability. A study of 24 individuals with diagnosed FHP of various ages (R_{age} = 25-40 years) were randomized into two groups to compare McKenzie Exercises as a control (n=12) to experimental respiratory feedback (n=13).¹² Baseline SCM and scalene activation was measured with surface EMG in addition to NDI score and CVA angle. The feedback respiratory exercise group performed the intervention 30 minutes per day, four times a week for two weeks. The exercise consisted of seven sets of 29-30 breaths per minute for two minutes with a two-minute rest between sets. Participants received respiratory feedback from a SPIROTIGER®. The control McKenzie Exercise group performed seven exercise motions for 10 seconds repeated 15-20 times. Paired t-tests within-groups performed by the researchers documented significant changes for all variables between baseline and post-intervention at two weeks for both control and experimental groups.¹² However, an ANCOVA between-groups outlined significant differences in NDI score ($p<.05$) and SCM activation ($P<.01$) with greater improvements on subjects in the experimental group.¹² The table below summarizes the study results in greater detail.

Table 6. Effect of Feedback Respiratory Exercise on Muscle Activation, CVA, and NDI (N=24)¹²

Variables	Experimental (M+SD)	Control (M+SD)	p-value ANCOVA
SCM (%) Pre-test	40.3 + 4.8	38.3 + 5.1	p <.01
SCM (%) Post-test	59.8 + 4.4 ***	49.2 + 4.4*	
Scalenes (%) Pre-test	47.2 + 5.2	44.9 + 6.3	Not-significant
Scalenes (%) Post-test	56.2 + 5.3 *	51.3 + 4.8*	
CVA (degrees) Pre-test	47.3 + 3.1	46.8 + 2.8	Not-significant
CVA (degrees) Post-test	55.1 + 2.5 *	52.5 + 3.4*	
NDI (points) Pre-test	17.6 + 1.8	17.1 + 1.5	p <.05
NDI (points) Post-test	12.3 + 1.1 ***	14.9 + 1.1*	

*p <.05; **p<.01; ***p<.001 based on paired t-test results

The results of this study were performed on a small sample of participants from one medical institution, and therefore lack generalizability to a greater population. Also, other variables such as medication usage and lifestyle were not controlled for in this experiment. Nevertheless, the results of this study indicate that respiratory feedback exercises decrease neck disability, pain and FHP by increasing SCM and scalene muscle activation.¹² McKenzie exercises were also demonstrated to be effective, however, they may be less effective at decreasing disability and pain and have less effect on increasing SCM activation.¹²

2.2. Conclusion

The exponential cost of neck pain, both monetary and emotional, has made research for neck pathology treatments an important category in literature. The COVID-19 pandemic may be increasing neck pain cases due to mask-wearing mandates.¹¹ Many promising treatment possibilities exist for neck disability including varying strength and stretching programs, ICT, and Kinesio® tape application. However, more research is necessary to determine the most economical treatment in terms of both time and money. While validation for the use of strengthening and stretching programs exist in literature, Kinesio® tape is one possible treatment application with proposed immediate effects on pain and disability that could be completed at-

home with little to no side effects. The lack of sufficient evidence in relation to type of cervical tape application that is most effective must be remedied before Kinesio® Tape can be widely prescribed. This study has the opportunity to validate one specific Kinesio® Tape procedure to alleviate neck pain and disability on participants wearing masks due the COVID-19 pandemic.

CHAPTER 3. METHODOLOGY

3.1. Purpose

In many parts of the United States, the recent and growing COVID-19 pandemic has made mask-wearing mandatory at indoor and outdoor activities where social distancing cannot be maintained. Healthcare workers and essential personnel have been required to wear masks throughout long work shifts and have reported adverse side effects.¹¹ Previous research has demonstrated a relationship between mask-wearing and headaches or neck pain.¹¹ Neck pain, associated to mask wearing or from other causes such as posture, creates economic and personal burdens.⁶ In fact, the medical care expenditures for neck pain annually in the United states have been estimated at \$86 billion,⁷ and neck pain has been ranked as the fourth greatest contributor to disability globally.⁶ In order to maintain work productivity and quality of life, an affordable and quick, at-home treatment to alleviate neck pain is a necessity.

Promising research has been published on the use of Kinesio® tape to treat upper body injuries and postural abnormalities such as rounded shoulder posture (RSP) and forward head posture (FHP).^{1-4,13,26} The tape's advertised "skin-like" properties are hypothesized to assist with tissue alignment, edema removal, and to increase range of motion.⁵ These properties combined with its accessibility and affordability have made it a viable option for neck pain treatment.²⁶ Additionally, it is possible to use at-home with the only documented side effect being cutaneous irritation.³

The purpose of this study was to determine if Kinesio® Tape could alleviate neck pain and improve cervical range of motion on a mask-wearing population. One method of quantifying improvements in neck disability is through measurement of active cervical range of motion (ACROM). A decrease in ACROM has been documented in association with neck pain in two

experimental studies and identified as a useful variable to determine patient prognosis and recovery with rehabilitation.^{8,42} A numerical pain scale rating (NPRS) and participant score on a mask-associated pain questionnaire was utilized in this study to examine perceived changes in pain and the effects of mask wearing on neck pain. The mask-associated pain questionnaire was a modified version of the questionnaire from the Ong et al, 2020 study: Headaches Associated With Personal Protective Equipment (HAPPE).¹¹ The study questionnaire was shortened and changed to reflect the research question for this study. The following research question guided this study:

Q1: To what extent does Kinesio® Tape change degrees of motion of the cervical spine? Subsequently, to what extent does Kinesio® Tape alter perceived neck pain?

3.2. Participants

This study included 30 participants ($n_{\text{males}}=10$; $n_{\text{females}}=20$; $M_{\text{age}}=26.13\pm5.44$; $M_{\text{height}}=66.8\pm4.34$; $M_{\text{weight}}=185.9\pm49.31$) with a mean NDI score of 16.37 ± 2.49 . The Neck Disability Index (NDI), a patient-reported outcome, has been used in clinics for diagnosis of neck pain and classification of pain severity.¹³ The NDI is the most commonly used neck-related, patient-reported outcome being cited in over 350 scientific articles and utilized in over 100 treatment studies.¹⁹ It has strong psychometric properties and therefore has been recommended for research and clinical applications.³⁸

The participants were recruited from a convenience sample via email listserv and word-of-mouth at North Dakota State University. No participants were excluded from the study for having any of the following items: (1) cervical disc pathology or injury; (2) previous neck surgery; (3) prior history of general medical conditions involving joints, muscles, bones or connective tissue such as fibromyalgia, osteoporosis, etc.; (4) an NDI score of less than 14 or

more than 24; (5) reported allergies to Kinesio® Tex Tape or any other adhesive material, and (6) any contraindications for the usage of Kinesio® Tape.

No participants were excluded from the study for having an NDI score of less than 14 points. The NDI exclusion criteria was created to ensure that the participant's neck pain was significant enough to require treatment. Additionally, those with a score of more than 24, which indicates complete disability, would have been excluded for their inability to perform ACROM measurements.¹³

All the participants that completed the study received \$10 for compensation. Both verbal and written consent were obtained from each participant before enrollment.

3.3. Setting

This was an experimental laboratory study performed in the Bentson Bunker Fieldhouse on the North Dakota State University Campus. The exact address was: Room 24, 1301 Centennial Blvd. Fargo, ND 58108. The athletic training classroom provided ease of access for participants and was a safe location to store necessary testing materials.

3.4. Equipment

Two-dimensional (2D) motion analysis using DartFish® Version 10 (Dartfish, Fribourg, Switzerland) was used to measure ACROM on participants at baseline and immediately after tape application. A similar technology, three-dimensional motion analysis of cervical motion, has been documented as both valid and reliable in comparison to the commonly used CROM device.^{48,49} However, based on the current and published research available, this was one of the first studies to use 2D motion analysis to analyze the effects of Kinesio® Tape on ACROM.

Kinesio® Tape, Tex Gold FP, was used for the intervention in this study. Specific facilitatory muscle benefits and tissue decompression were created by the amount of stretch

applied to the tape on the skin.⁵ The tape was 100% cotton material with polymer elastic strand that is the same as thickness as the skin.⁵ It was latex-free and contained a heat activated adhesive.⁵ The Kinesio® Tape was waterproof and adhesive with a width of 5 cm and a thickness of 0.5 mm.⁵

3.5. Procedures

Data collection was approved by North Dakota State University's Institutional Review Board (IRB). The data was collected during the spring of 2021. Research was performed in room 24 of Bentson Bunker Fieldhouse on the NDSU campus. The participants signed an Informed Consent before data collection began. Additionally, the participants were screened for COVID-19 symptoms and exposure before completing the study. No participants reported COVID-19 symptoms or exposure.

Baseline NDI scores were recorded first to determine participants' eligibility. The NDI questionnaire is the most effective and widely accepted means for self-assessment of neck pain.^{15,19} The form consists of ten questions, each rated on a six-point Likert-type scale (0-5 points) with a maximum score of 50 points reflecting the most severe level of neck disability. A total score of 0–4 indicates no disability, 5–14 a mild disability, 15–24 a moderate disability, and 25–34 a complete disability.¹³ The questions examine the severity of neck pain with activities of daily living such as personal care, lifting, reading, headaches, concentration, work, driving, sleep, and recreation.

An additional questionnaire was given on the perceived effect of mask wearing on neck pain. The questionnaire used in this study was adapted from the HAPPE study¹¹ but included fewer and less specific questions. Questions included information on neck pain episodes before

and after COVID-19, average number of hours a day mask is worn, and perceived effect of mask-wearing on neck pain.

ACROM was measured using 2D motion analysis on the Dartfish® Version 10.0 (Dartfish, Fribourg, Switzerland) software. Measurements were collected for cervical flexion, extension, lateral side bending to the right and left, and cervical rotation to the right and left. The participants performed flexion, extension, and left and right lateral flexion while seated with arms relaxed at their sides.^{48,49} Left and right rotation were performed supine with arms resting on the table at their sides. They were instructed to move from a neutral forward glance to their non-painful end range. The patient performed each movement three times before moving to the next, and the average of the three was calculated for each direction. The motions were video recorded with a camera (Casio EX-FH20, Tokyo, Japan) 1.5 meters from the participant. The camera was focused to the side of the head for flexion and extension, behind the head for left and right lateral flexion, and over the crown of the head for rotation. The video was later analyzed in Dartfish® Version 10.0 to calculate the end-range angle for each movement by one researcher to eliminate inter-rater error.⁶⁰

Perceived neck pain on a 11-point numerical scale (NPRS) was recorded at baseline, after baseline ACROM, 20 minutes after the application of the tape intervention, and again after post-application ACROM. NPRS ratings were taken immediately after performing ACROM to determine perceived pain with cervical movement, whereas baseline and post-tape application measurements were to determine stationary neck pain.

The Kinesio Taping Method® utilized in this study was a muscle activation correction, performed to facilitate underactive muscles. The application was applied with appropriate stretch and neck positioning per instructions by Kinesio® Tape International. In order to increase the

activity of underactive muscles, the tape was applied from origin to insertion with 15-25% tension.⁵ The Kinesio® Tape mechanical muscle correction was performed with one Y-strip of Kinesio® Tape over the bilateral cervical multifidus and semispinalis cervicis muscles,³⁷ but also included portions of other cervical extensor muscles (the semispinalis capitis, splenius cervicis, levator scapulae, upper trapezius, longus coli, and splenius capitis).^{35,36,59} Additionally, a space correction web cut with four cuts in one I-strip was used over the mid-cervical region to decrease tissue decompression and local edema.⁵ The tension applied was approximately 25%.⁵ This application was used and found effective in a similar study on the effects of Kinesio® Tape with whiplash associated neck pain.²

Throughout the duration of data collection, the participant wore a mask for personal protection and for the protection of the researcher. The two tape strips were applied to the participant while they were seated with arms relaxed at the sides.² The first strip, a Y-strip, was placed over the bilateral cervical multifidus and semispinalis cervicis muscles³⁷ and applied from muscle origin to insertion with paper-off tension (15-25%).² The tape was anchored over the thoracic vertebrae T1-T2 with no tension; then, each tail was applied with the patient's neck in a position of cervical contralateral side-bending, rotation, and flexion. The tails were anchored at the C1-C2 cervical vertebrae region (or as high as the hairline allowed), with no tension. The second strip, a web cut for space correction, was placed perpendicular to the Y-strip over the mid-cervical region (C3-C6), with the patient in cervical spine flexion. The ends were anchored with no tension and 25% tension was applied for the taping procedure.

Twenty minutes following application of the tape, ACROM and neck pain were reassessed. Kinesio® Tape International recommends waiting 30-minutes after tape application before activity.⁵ However, the tape was applied for twenty minutes in this study prior to

recording post-intervention results to give the tape enough time to take effect. Thirty minutes was not necessary since there was no concern for heavy sweating or activity requirements. No participants reported skin irritation or discomfort from the tape.

3.6. Data Analysis

SPSS Version 25 on Windows was used for statistical analysis of the collected data. Change in cervical range of motion measurements with and without Kinesio® tape were assessed using paired samples *t*-tests. A repeated measures analysis of variance (ANOVA) was used to assess change in reported neck pain between four different conditions: 1) no tape and no motion; 2) no tape with motion; 3) tape and no motion; 4) tape with motion. Pairwise comparisons were performed to indicate the significant differences between conditions.

3.7. Conclusion

The purpose of this study was to determine if Kinesio® Tape could alleviate neck pain and disability on masked participants. Patient-reported pain ratings on the NPRS and ACROM were used to determine changes in neck pain and disability. The COVID-19 pandemic continues to affect more people every day and a solution to PPE-associated neck pain is a necessity. Kinesio® Tape can provide an affordable, at-home treatment to relieve pain and increase productivity in healthcare workers, essential personnel, and the general population.

CHAPTER 4. MANUSCRIPT

4.1. Abstract

Background: Researchers have documented promising results supporting the use of Kinesio® Tape to treat shoulder and neck pain.^{2-4,13,26,61,62} However, many of these studies use vague or incorrect taping procedures per the Kinesio® Taping method and research the tape in combination with other treatments.

Purpose: The purpose of this study was to determine if Kinesio® Tape could alleviate neck pain and improve cervical range of motion on a mask-wearing population.

Study Design: Randomized controlled trial

Methods: Thirty participants with a Neck Disability Index (NDI) score of 14 or more acted as their own controls, performing active cervical range-of-motion and reporting neck pain (11-point numerical pain rating scale) at baseline and 20-minutes after the Kinesio® Tape application.

Results: Statistical significance was determined with an $\alpha=.10$. Paired samples *t*-tests on change in cervical range of motion measurements with and without Kinesio® tape application revealed a significant increase in cervical left lateral flexion in the taped condition compared to no tape ($t[29]=-2.626, p=.014$). Additionally, cervical extension ($t[29]=-1.740, p=.093$) and right rotation ($t[29]=-1.964, p=.059$) demonstrated significantly increased range of motion with tape. A repeated measures analysis of variance (ANOVA) on neck pain revealed a significant change in neck pain ($f[3]=18.719, p<.001$), indicating pain improved with the tape application for both stationary and motion conditions.

Conclusion: Patients with moderate neck pain experienced immediate and statistically significant improvements in neck pain and cervical extension, left lateral flexion, and right

rotation with a Kinesio® Tape application to facilitate the semispinalis cervicis and cervical multifidus muscles and decrease tissue compression. However, the magnitude of change was small and may lack clinical meaningfulness. Future research should examine long-term taping and patient perceived functional changes.

Level of Evidence: 1b

Key Terms: cervical spine, Kinesio® Tape, neck, mask

Clinical Relevance: Kinesio® Tape is an alternative therapy option that can be performed by the patient at home with only one documented side-effect of cutaneous irritation.³ The tape can decrease patient-reported pain and increase cervical range of motion to assist in activities of daily living or improve therapy outcomes.^{2-4,13,26}

What is known about the subject: Neck pain is the 4th greatest contributor to overall disability and is estimated to effect 13.3% of the population.^{6,63} Neck pain has been cited to decrease cervical range of motion¹⁹ and lead to decreases in quality of life.⁶

What this study adds to existing knowledge: The taping procedure used in this study targets specific muscles (cervical multifidus and semispinalis cervicis) that exhibit decreased firing in neck pain patients^{36,37} and creates space in the superficial tissues through decompression.² The specificity of the taping procedure used in this study has valuable and replicable properties, consequently it can be used in clinical settings to decrease neck disability. It may be utilized by physical therapist and healthcare professionals.

4.2. Introduction

The Global Burden of Neck Pain 2010 study defines neck pain as “pain in the neck with or without pain referred into one or both upper limbs that lasts for a least one day.”^{6(p1309)} The incidence rate of neck pain varies between countries, but in the United States it is estimated that

neck pain affects 13.3% of the population and leads to medical care expenditures approaching \$86 billion annually.⁷ The cause of neck pain is often multifactorial with risk factors including occupation, age, posture, and mask-wearing during the COVID-19 pandemic.^{9,11,27,31} Specific occupational sectors have increased risk and higher prevalence of neck pain. The top five occupational groups with an increased prevalence of neck pain include (1) military, (2) health care support, (3) arts, design, entertainment, sports, and media, (4) community and social services, (5) and personal care and services.⁷ Neck pain also varies in severity, but globally it ranks as the fourth greatest contributor to disability.⁶³ The ongoing effects of neck disability can lead to changes in quality of life, decreases in work productivity, and changes in mental health.^{6,33}

Due to the sudden onset, uncertain end, and national mask-wearing mandates associated with the COVID-19, a unique opportunity has arisen in research to discover and validate treatments that improve quality of life from the side-effects caused by the pandemic.¹¹ Therefore, the novel examination of mask wearing in conjunction with neck pain should be explored since an immediate, safe, and effective treatment is a priority, especially for high-risk populations such as healthcare workers.⁷

Health care workers were on the frontlines since the beginning of the COVID-19 pandemic and required to wear personal protective equipment (PPE), such as masks and goggles, throughout long work shifts.¹¹ This sudden shift in work attire combined with the necessity to continue providing care for others during long work shifts, put them in need of a solution for immediate pain reduction and functional increases. As frontline workers often putting in long-hours while wearing PPE, there is a need for treatments to improve neck function and decrease neck pain in healthcare workers.

Physical therapists and athletic trainers often treat neck pain with prolonged rehabilitation programs focused on improving cervical extensor muscle strength and flexibility.^{12,16,17} The McKenzie and Kendall exercise programs are two common treatment regimens for neck pain.¹⁵ The McKenzie exercise program focuses on mobilization and manipulation of the neck with an emphasis on stretch exercises.¹³ In comparison, the Kendall exercise program strengthens shoulder retraction and deep cervical flexor muscles while stretching the pectoral muscles.¹⁸ One study merged the two programs and examined their combined effectiveness over 8-weeks.¹⁵ Of the three groups examined, performing the exercises once, twice, or three times daily, the greatest improvement in range of motion was observed in subjects performing the exercises three times daily for 8-weeks.¹⁵ However, pain may inhibit a patient's ability to perform rehabilitation exercises, and current evidence-based programs require weeks to months of therapy before results. At-home and immediate relief from symptoms and improvement in neck function is essential for work productivity and quality of life.

Kinesio® Tape is a proposed solution to providing immediate neck pain relief and improvement in function.²⁻⁴ The tape and its many applications have grown in popularity due to advertised benefits such as increased local circulation, reduced local edema, facilitation of muscles, positional stimulus, and improvement in range of motion.¹⁻⁵ While the advertised benefits appear promising and applicable for the treatment of neck pain, scientific evidence on its effectiveness is limited. Several published studies have documented evidence of its improvement in shoulder and neck range of motion and improved outcomes when used in conjunction with physical therapy to treat neck pain.^{1-4,26} The most relevant study to highlight used Kinesio® Tape alone to treat whiplash-associated disorders (WADs).² Over a 24-hour period, pain significantly decreased and cervical range of motion improved compared to a sham tape group.

However, the population was limited to patients with WADs that had been referred to physical therapy.

Considering the strengths and limitations of previous research in terms of population and taping procedure, the current study was designed to test a muscle-specific cervical taping procedure in combination with a space correction application on allied healthcare subjects with neck pain. The specific muscles targeted were the bilateral cervical multifidus and semispinalis cervicis because they have been documented to have decreased firing and function in neck pain patients.^{9,36,37} Additionally, a space correction strip was applied to decrease tissue decompression and local edema.^{2,5} The purpose of this study was to determine if Kinesio® Tape could alleviate neck pain and improve cervical range of motion on a mask-wearing population. Based on the implemented methodology, we hypothesized the targeted taping procedure would exhibit decreased neck pain and improved cervical range of motion.

4.3. Methods

4.3.1. Participants

Volunteer participants were recruited from the Fargo/Moorhead metropolitan area. They included students from a large university as well as community members. The sample consisted of 30 participants ($n_{\text{male}}=10$, $n_{\text{female}}=20$) with an average age of 26 ± 5.44 (additional demographic information presented in table 7). The study was approved by North Dakota State University's Institutional Review Board (IRB). Participants were screened for eligibility using the Neck Disability Index (NDI). The NDI questionnaire is the most effective and widely accepted means for self-assessment of neck pain.^{24,25} The form consists of 10 questions, each rated on a six-point Likert-type scale (0-5 points) with a maximum score of 50 points reflecting the most severe level of neck disability. The questions examine the severity of neck pain with activities of daily living

such as personal care, lifting, reading, headaches, concentration, work, driving, sleep, and recreation. Once deemed eligible for the study by scoring between a 14-24 on the NDI, demographic data, including age, gender, profession, mask-wearing habits, and perceived effects of mask wearing on neck pain were recorded.

The inclusion criteria were current neck pain and NDI score of at least 14, indicating moderate neck disability requiring treatment.¹³ Participants were excluded from the study if they had any of the following items: (1) cervical disc pathology or injury; (2) previous neck surgery; (3) prior history of general medical conditions involving joints, muscles, bones or connective tissue such as fibromyalgia, osteoporosis, etc.; (4) an NDI score of less than 14 or more than 24; (5) reported allergies to Kinesio® Tex Tape or any other adhesive material, and (6) any contraindications for the usage of Kinesio® Tape. No participants were excluded for meeting exclusion criteria. All the participants signed an Informed Consent and were screened for COVID-19 symptoms and exposure before completing the study.

4.3.2. Procedures

Data on mask-wearing habits, and perceived effects of mask wearing on neck pain were recorded using a questionnaire. The questionnaire used to collect the referenced data was adapted from the Ong et al., 2020 study on Headaches Associated With Personal Protective Equipment (HAPPE).¹¹ The version used in the current study included fewer and less specific questions to maximize applicability for neck pain episodes before and after COVID-19. Questions included information on neck pain episodes before and after COVID-19, average number of hours a day mask is worn, and perceived effect of mask-wearing on neck pain.

Other outcome measures for this study included perceived pain rating on an 11-point numerical pain rating scale (NPRS) and active cervical range of motion (ACROM). Pain

measurements were recorded at baseline, after baseline ACROM, 20 minutes after the application of the tape intervention, and again after post-application. Cervical range of motion for flexion, extension, and left and right lateral flexion was assessed with the participant seated in flat back chair, hips and knees at 90° of flexion, and straps around the waist and shoulders to ensure motion was only from the neck.^{48,49} The camera was facing the side of the head for flexion and extension and the back of the head for left and right lateral flexion. Rotation was recorded with the patient supine on a treatment table, arms by their sides, and the crown of the head facing the camera. Video data was recorded on a standard video camera (Casio EX-FH20, Tokyo, Japan) 1.5 meters away from the participant. Participants were instructed to perform each motion three times to a non-painful end range. Tape markers were placed over the bilateral acromion, tip of the nose, and C7 spinous process by one certified athletic trainer to eliminate inter-evaluator error.⁶⁰ The purpose of the markers was to determine angles using typical biological landmarks like those used with goniometric assessment of cervical motion. Measurements were collected for cervical flexion, extension, lateral flexion to the right and left, and cervical rotation to the right and left. The analysis was performed using Dartfish Version 10.0 (Dartfish, Fribourg, Switzerland) for each end-range motion measurement. An average measurement was calculated from three trials of each movement. Only one researcher analyzed the range of motion data to remove inter-rater error.^{45,60}

All the participants received the Kinesio® Tape treatment after completing baseline ACROM. A muscle activation correction to facilitate underactive muscles was applied over the bilateral cervical multifidus and semispinalis cervicis muscles by one certified Kinesio® Taping Practitioner to eliminate inter-rater error.^{2,9,26,37} Two strips were applied with 25% tension over the treatment zone and anchored with no tension. The first strip applied, a Y-cut, was anchored

over the T1-T2 thoracic region and the C1-C2 cervical region. The patient was in cervical contralateral side-bending, rotation, and flexion for the application. The second strip, a web cut for space correction, was placed perpendicular to the Y-strip over the mid-cervical region (C3-C6) with the patient in cervical spine flexion. The space correction strip was applied to decrease tissue decompression and local edema.⁵ This same application was used and found effective in a similar study on the effects of Kinesio® Tape with whiplash associated neck pain.² Twenty minutes following tape application, ACROM and neck pain was reassessed.



Figure 1. Kinesio® Tape Procedure.

4.4. Statistical Analysis and Results

Independent variables for the present study included the presence or absence of Kinesio® tape. Dependent variables included change in range of motion (flexion, extension, lateral flexion, and rotation) and pain. Descriptive statistics and frequency data for demographic information, NDI score, and mask wearing are presented in Table 7.

Table 7. Descriptive Statistics and Frequencies for Demographic Information & Neck Pain

Variable	Mean	Standard Deviation
Age (years)	26.13	5.44
Height (inches)	66.8	4.34
Weight (lbs.)	185.9	49.31
NDI	16.47	2.49
Variable	Categories	Frequency (%)
Sex	Male	33.3
	Female	66.7
Profession	Nurse	6.7
	Nursing Student	6.7
	Athletic Trainer	36.7
	AT Student	3.3
	Physician	16.7
	Respiratory therapist	3.3
	Massage therapist	6.7
	Ex. Sci. Student	3.3
	Biology Student	10
	Medical Engineer	3.3
	HNES Staff	3.3
Neck pain days/month pre-COVID	<1	3.3
	1-4 days per month	26.7
	5-9 days	36.7
	10-14 days	16.7
	>= 15 days	16.7
Neck pain days/month since COVID	<1	3.3
	1-4 days per month	26.7
	5-9 days	30
	10-14 days	16.7
	>= 15 days	23.3
Change in the average number of days per month where neck pain is experienced	Significant increase	10
	Slight increase	33.3
	No change	53.3
	Slight decrease	3.3
	Significant decrease	0
Change in the average duration of each neck pain attack	Significant increase	10
	Slight increase	30
	No change	60
	Slight decrease	0
	Significant decrease	0
Overall, the change in frequency of PPE (facial mask) usage during the COVID- 19 outbreak has affected the control of my pre-existing neck pain.	Strongly agree	3.3
	Agree	10
	Neutral	50
	Disagree	10
	Strongly disagree	26.7
In your opinion, how likely is this new neck pain attributed to the usage of facial mask alone?	Very likely	3.3
	Likely	16.7
	Maybe	23.3
	Unlikely	20
	Very unlikely	36.7

Change in cervical range of motion measurements with and without Kinesio tape application were assessed using paired samples *t*-tests. Results of the paired samples *t*-tests revealed a significant increase in cervical left lateral flexion in the taped condition compared to no tape ($t[29] = -2.626, p = .014$). Additionally, cervical extension ($t[29] = -1.740, p = .093$) and right rotation ($t[29] = -1.964, p = .059$) demonstrated significantly increased range of motion with tape applied at $\alpha = .10$. Descriptive statistics for cervical range of motion measurements are presented in Table 8.

Table 8. Descriptive Statistics for Cervical Range of Motion with & without Tape

ROM	Tape Condition	Mean	Standard Deviation
Flexion	No Tape	47.81	12.80
	Tape	50.18	10.09
Extension	No Tape	52.04	9.55
	Tape	54.48	10.58
L Lateral Flexion	No Tape	37.03	7.00
	Tape	40.18	6.70
R Lateral Flexion	No Tape	35.76	8.60
	Tape	35.55	10.22
L Rotation	No Tape	69.31	10.66
	Tape	69.99	10.47
R Rotation	No Tape	69.18	9.21
	Tape	72.16	9.17

A repeated measures analysis of variance (ANOVA) was used to assess change in reported neck pain in four different conditions: 1) no tape and no motion; 2) no tape with motion; 3) tape and no motion; 4) tape with motion. Descriptive statistics for reported pain are presented in Table 9. Results of the ANOVA revealed a significant change in neck pain ($F[3] = 18.719, p < .001$). Pairwise comparisons indicate the significant differences occurred between conditions 1 and 3 ($p = .001$), 1 and 4 ($p = .001$), 2 and 3 ($p < .001$), and 2 and 4 ($p < .001$).

Table 9. Descriptive Statics for Reported Pain

Condition	Mean	Standard Deviation
1) No tape & no motion	2.77	1.36
2) No tape with motion	3.17	1.74
3) Tape & no motion	1.80	1.37
4) Tape with motion	1.77	1.50

4.5. Discussion

The results of the current study demonstrated that Kinesio® Tape can decrease neck pain and improve cervical range of motion immediately in patients with neck pain. After receiving the application, participants had statistically significant changes with cervical left lateral flexion, cervical extension, and right rotation motions compared to baseline measurements. Additionally, participants reported statistically significant decreases in neck pain after application of the tape. These changes occurred at all collection points, indicating a decrease in neck pain after application of the tape.

The results of the current study agree with previous randomized control trials that also found improvements in cervical range of motion and neck pain after application of Kinesio® Tape to the cervical spine.^{2-4,26,62} Further, the design and magnitude of changes demonstrated in the current study are similar to those of a randomized control trial by Gonzalez-Iglesias et al.² who investigated the short-term effects of Kinesio® taping on patients with Whiplash Associated Disorders (WADs). The taping procedure used by Gonzalez-Iglesias et al.² was a Y-strip over the posterior cervical extensor muscles with paper-off tension and a web strip over the mid-cervical region. The taping procedure differed from our study by specificity of muscle targeting with our study identifying the semispinalis cervicis and cervical multifidus.^{9,37} The results of the Gonzalez-Iglesias et al.² study were of similar magnitude to our results. Reported improvement in flexion was 2.7° (CI 1.0-4.6), extension 8.1° (CI 6.2- 9.9), left lateral flexion 2.7° (1.0-4.6),

and neck pain on average decreased by one point (CI: -1.2 to -0.8) on the NPRS. Our replication of results from the Gonzalez-Iglesias et al.² study on a broader demographic of patients and with a more specific and replicable taping procedure improves the validity of using Kinesio® Tape to treat neck disability.

The statistically significant findings that were observed from the non-tape to tape condition for cervical left flexion, extension, right rotation, and pain are promising evidence in support of Kinesio® Tape to improve neck pain and function in the short-term. It must be noted though that the magnitude of changes lack clinical relevance per common cited minimal detectable change (MDC) amounts.² The reported MDC for cervical range of motion is 3.6°-6.5°.³ The mean changes for cervical motion in this study were 2.44° for extension, 3.15° for left lateral flexion, and 2.98° right rotation. The MDC reported for pain on the NPRS is two-points, regardless of baseline pain.^{23,24} In the current study the average change in pain was 1.4 points from no-tape with motion to tape with motion conditions. However, the current study only examined the immediate effects of Kinesio® Tape, and it is plausible that greater effectiveness may be observed over extended wear time or multiple treatments. For this reason, additional research, especially on extended wear of the tape, is important to document clinical significance in addition to statistical significance.

While the actual mechanism for the tape's effectiveness remains unknown, there are several hypotheses to explain our findings. The semispinalis cervicis and cervical multifidus have been documented to have decreased activity³⁷ and be undeveloped in neck pain patients.³⁶ Bilateral contraction of these muscles causes neck extension while unilateral contraction leads to ipsilateral lateral flexion and contralateral rotation. By facilitating these muscles with the underactive muscle taping application, it would be expected that muscle firing and consequently

function would improve.⁵ Another possibility is that tension in the tape provided afferent stimuli, facilitating pain inhibitory mechanisms (gate control theory), thereby reducing patients' pain levels and allowing improvement in motion.²

Decompressing the tissue with the web cut strip may have decreased perceived pain.⁵ The proposed hypothesis for this action is by the creation of a suction-like force, which lifts the structures and increases tissue space.⁵ The decrease in interstitial space in turn creates space between the skin and superficial structures to allow for lymphatic drainage and pain reduction.⁵ A space correction in combination with muscle facilitation was documented to decrease pain in the Gonzalez-Iglesias et al.² randomized control trial and the current study. However, due to the combined approach of using the muscle facilitation and decompression applications, it cannot be determined if one application alone caused the change or if it was the combination of both applications.

The lack of significant changes in right lateral flexion and left rotation could have been due to an underlying unilateral first rib dysfunction, which has been cited to limit contralateral rotation and ipsilateral flexion of cervical spine on one side of the body.⁶⁴ It is hypothesized the decrease in range of motion from the first rib is a hitching of the first thoracic vertebra transverse process against the elevated rib.⁶⁴ Neck pain is common symptom of first rib dysfunction, therefore our subjects may have experienced a first rib dysfunction as well, which is supported by our bilateral comparison of right (35.76 ± 8.60) and left (37.03 ± 7.00) lateral flexion at baseline. Expanding further, hand dominance alone or in combination with a first rib dysfunction may have affected cervical range of motion. Documented decreases in right lateral flexion for right-hand dominant individuals with neck pain has been cited due to decreased upper trapezius length from overactivation on the dominant arm.⁴² The restriction created from the

shortened trapezius muscle limits neck motion for contralateral rotation and ipsilateral lateral flexion.⁴² Future research is necessary on unilateral differences caused by hand dominance and first rib dysfunction to determine their correlation to neck motion.

It should also be noted that the splenius capitis muscle was cited in one study to have decreased activity in neck pain patients and this muscle was not specifically targeted in this study.³⁷ Targeting the splenius capitis could improve patient outcomes more. However, the scope of this study was limited to determining if the tape application could improve neck motion and pain and the mechanism of action for the tape requires further investigation.

A federal mask-mandate to prevent the spread of COVID-19 required the use of masks indoors and at functions where social distancing could not be maintained, thereby requiring subjects in this study to wear a mask throughout the duration of data collection. A recent study by Ong et al.¹¹ documented increases in intensity, duration, and frequency of headaches and associated neck pain in health care workers due to mask wearing. Due to mask requirements for the current study and potential confounding variable of mask wearing on neck pain, participants' perceived affect of mask wearing on neck pain was examined as a secondary outcome.

While a previous study by Ong et al.¹¹ documented increases in headaches and neck pain in health care workers due to mask wearing, mask associated pain was a novel outcome measure for Kinesio® Tape studies. In order to investigate an association between mask wearing and neck pain frequency and intensity, subjects completed a mask-associated pain questionnaire. Six subjects (20%) reported an increase in neck pain days per month after the COVID-19 pandemic. However, the majority of participants answered neutral or in disagreement that mask wearing was affecting their neck pain in terms of frequency or length of attack. Our results may differ from the Ong et al. 2020¹¹ study in magnitude of subjects reporting mask associated neck pain

for several reasons. In the Ong et al. 2020 study,¹¹ the subjects were donned in goggles, N95 masks, and facial shields while the subjects in the current study were wearing cloth or disposable masks.¹¹ Additionally, the Ong et al. 2020¹¹ study was performed recently after the COVID-19 pandemic commenced, therefore other components such as stress and increases in work hours or shift length may have affected the results.¹¹ Future research is required on the use of personal protective equipment and its effects on neck pain.

Several limitations were present in this study. The population used was from one metropolitan area and narrowed to only allied healthcare personnel, which may not be representative of a larger population. Additionally, this study only examined the immediate effects of Kinesio® Tape on neck pain and cannot infer long-term effects. An $\alpha=.10$ was utilized for data analysis to minimize Type II error based on the expected small magnitude of change in cervical range of motion and pain based on past published literature. The goal of this study was to improve quality of life and decrease disability, and even small changes in motion and pain may accomplish this goal. The results of this study indicate immediate improvements in pain and range of motion from wearing the tape for only 20 minutes. Additional research on extended wear of the tape may provide larger magnitudes of change in pain and motion, therefore warranting a lower alpha level to decrease Type 1 error. The tape procedure could have differed between participants by tension and location due to the nature of tape. However, the use of one certified Kinesio® Taping Practitioner provided increased reliability.²⁶ Also, using both the space correction and muscle facilitation applications together limits the ability to hypothesize the tape's mechanism of action. A future study applying only one application at a time would provide valuable information and differentiation for applications. A true control group and randomization of conditions was not implemented in this study due to the concern that the

benefits of the tape would continue after the tape was removed. However, a true control group and increased regulation over confounding variables such as medication usage would improve future study designs and results as well.

4.6. Conclusion

Patients with neck pain experienced immediate and statistically significant improvements in neck pain and cervical motion with a Kinesio® Tape application to facilitate the semispinalis cervicis and cervical multifidus muscles in addition to decompression of superficial neck tissues. The difference between the current study and past research was the specificity of the muscles targeted with the tape application. By applying the tape on targeted muscles and with appropriate direction and stretch per the Kinesio® taping method, this taping procedure can be replicated in the future to achieve similar results to those documented in this study. However, additional research, including research on extended wear of the tape, is necessary to determine clinical significance. Future research should examine extended wear of the taping application using the muscle specific procedure documented in this study. Additionally, the relationship between frequency and intensity of neck pain for those who are required to wear personal protective equipment should be investigated with Kinesio® Tape as a possible mitigating treatment.

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APPENDIX. MASK WEARING QUESTIONNAIRE

Mask Wearing and Neck Pain Survey: Adapted from HAPPE Study¹¹

Directions: Answer/pick the single answer that best describes your response to the question.

Age: _____

Sex: _____

Height: _____

Weight: _____

Profession or college major: _____

Demographic information on pre-existing neck pain before COVID-19 pandemic

Average <u>number of days per month</u> where neck pain is experienced.	<input type="checkbox"/> <1 day per month (i.e. no monthly attacks) <input type="checkbox"/> 1-4 days per month <input type="checkbox"/> 5-9 days per month <input type="checkbox"/> 10-14 days per month <input type="checkbox"/> ≥15 days per month
Associated symptom(s) during <u>EACH</u> neck pain attack (May select more than one option).	<input type="checkbox"/> None <input type="checkbox"/> Radiating Pain <input type="checkbox"/> Numbness and Tingling into extremities <input type="checkbox"/> Headache <input type="checkbox"/> Tenderness to touch <input type="checkbox"/> Stiff neck Others: _____

Demographic Information on mask-wearing behavior

PPE face mask type	<input type="checkbox"/> N95 mask <input type="checkbox"/> Cloth Mask <input type="checkbox"/> Disposable Surgical Mask <input type="checkbox"/> Others: _____
Average number of <u>hours</u> of face mask wear <u>per day</u> .	_____ hours per day
Number of <u>days</u> of face mask wear <u>over the last 30 days</u> .	_____ days

1. To what extent since the start of COVID-19 has there been a change in the **average number of days per month** where neck pain is experienced?

☐ Significant increase in frequency ☐ Slight increase in frequency
☐ No change in frequency
☐ Slight decrease in frequency ☐ Significant decrease in frequency

Demographic information on neck pain **after** mask-wearing and COVID-19 pandemic began

Average <u>number of days per month</u> where neck pain is experienced	<input type="checkbox"/> <1 day per month (i.e. no monthly attacks) <input type="checkbox"/> 1-4 days per month <input type="checkbox"/> 5-9 days per month <input type="checkbox"/> 10-14 days per month <input type="checkbox"/> ≥15 days per month
Associated symptom(s) during <u>EACH</u> neck pain attack (May select more than one option).	<input type="checkbox"/> None <input type="checkbox"/> Radiating Pain <input type="checkbox"/> Numbness and Tingling into extremities <input type="checkbox"/> Headache <input type="checkbox"/> Tenderness to touch <input type="checkbox"/> Stiff neck Others: _____

2. To what extent has there been a change in the **average duration of EACH neck pain attack?**

☐ Significant increase in duration ☐ Slight increase in duration ☐ No change in duration
☐ Slight decrease in duration ☐ Significant decrease in duration

3. **Overall**, the change in frequency of PPE (facial mask) usage during the COVID- 19 outbreak has affected the control of my **pre-existing** neck pain.

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly disagree

4. If your answer to the question above was '**strongly agree**' or '**agree**', has the change in your pre-existing neck pain affected your work performance?

☐ Significant increase in work performance. ☐ Slight increase work performance.
☐ No change in work performance. ☐ Slight decrease in work performance.
☐ Significant decrease in work performance.

5. List other possible factor(s) that may have contributed to the overall change in the control of your pre-existing neck pain.

<input type="checkbox"/> Sleep deprivation	<input type="checkbox"/> Physical stress	<input type="checkbox"/> Emotional stress (e.g. anxiety)
<input type="checkbox"/> Irregular mealtimes	<input type="checkbox"/> Insufficient hydration	<input type="checkbox"/> Lack of exercise <input type="checkbox"/> Others:

6. In your opinion, how likely is this NEW neck pain attributed to the usage of **FACIAL MASK** alone?

<input type="checkbox"/> Very likely <input type="checkbox"/> Likely <input type="checkbox"/> Maybe <input type="checkbox"/> Unlikely <input type="checkbox"/> Very unlikely
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