Dry needling latent upper trapezius myofascial trigger points and the immediate effects on cervical motor performance: A randomized controlled pre-post clinical trial

by

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Abbreviations

Randomized control trial (RCT)
Dry needling (DN)
Upper trapezius (UT)
Myofascial trigger points (MTrPs)
Range of Motion (ROM)
Cervical range of motion (CROM)
Visual analogue scale (VAS)
Neck disability index (NDI)
Pain pressure thresholds (PPT)
Local twitch response (LTR)
Target width (W)
Target amplitude (A)
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Movement time (MT)
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Peak Velocity (PV)
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Time to peak velocity (ttPV)
Time to peak acceleration(ttPA)
Constant error (CE)
Variable error (VE)

Abstract

Background: Dry needling (DN) is an efficacious intervention for recurrent cervical pain. However, there is a paucity of research on the impact of DN on motor performance using quantitative objective outcome measures.

Objective: The purpose of this study was to investigate the efficacy of DN compared to a sham needling procedure on latent upper trapezius (UT) myofascial trigger points (MTrPs) in participants with a recurrent history of neck pain.

Method: A blinded pre-post clinical trial was performed. Thirty-six volunteers (mean age 35) with recurrent neck pain and latent MTrPs in UT were randomly assigned to a DN or a penetrating sham group. A single needling intervention was performed. Clinical outcomes included active range of motion (ROM), pain with the visual analogue scale (VAS), Neck Disability Index (NDI) and pain pressure thresholds (PPT). A Fitts' Law-based head turning task assessed motor outcomes.

Results: Immediately following treatment both groups showed no change in pain ($p > 0.05$) or ROM ($p > 0.05$) while PPT was increased ($p < 0.001$). Pain was reduced at the one-week follow up ($p < 0.001$). Movement time (MT) was reduced in both groups after the intervention ($p < 0.001$). Both constant and variable error were also reduced post-intervention ($p < 0.001$, $p = 0.002$; respectively). An interesting trend was found with movement initiation (peak velocity and peak acceleration), where after the DN intervention participants' initial movement was faster; this trend was not seen in participants in the sham procedure group.

Conclusions: Needling interventions can impact central pain processing resulting in decreased pain perception, with subsequent reductions in MTs. These data suggest that DN triggered a sensorimotor response that altered or reset muscle activation patterns leading to different movement strategies.

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Dedication

I would like to dedicate this work to my parents Robert and Georgina Bone. The project provided some relief from mourning their recent passing. To my partner, Shep for his unwavering support and knowing the commitment necessary to complete a degree. To my daughter Elle, with the hope of being a role model to pursue her goals in all stages of her life.

Dry needling latent upper trapezius myofascial trigger points and the immediate effects on cervical motor performance:

A randomized controlled pre-post clinical trial

Introduction

Musculoskeletal neck pain is one of the major causes of disability and economic burden in the world (Hoy et al., 2014). The annual incidence of neck pain in the general population is 14.6% with 0.06% developing disabling neck pain and 22.8% of those with prevalent neck pain reported a recurrent episode (Côte et al., 2008). Mechanical neck pain is associated with myofascial pain syndrome (MPS) and cervical joint dysfunction (Fernandez de la Peñas et al., 2005). The prevalence of myofascial trigger points (MTrPs) in a myofascial pain population with chronic non-specific neck pain was 93.75% (Cerezo-Téllez et al., 2016). Systemic reviews with meta-analysis found dry needling (DN) myofascial trigger points of the upper quarter (Kietrys et al., 2013), cervical spine (Liu et al., 2015) and upper trapezius (UT) (Cerezo-Téllez, 2016) an effective treatment for immediate and short-term pain reduction. MTrP research disproportionately focuses on musculoskeletal conditions with active MTrPs and outcomes related to pain; a shift toward sensorimotor dysfunction and functional outcomes offers the potential to decrease the recurrent nature of neck pain.

Sensorimotor deficits have been observed with MTrPs and chronic pain conditions. The proposed mechanisms are centrally driven adaptations to pain and regional neuromuscular system modifications (Holm et al., 2002). Inhibition in the motor system with tonic muscle pain has been seen in experimental conditions (Le Pera et al., 2001). Resulting adaptations to pain

occur when the brain modifies its motor commands in response to pain and include reduced muscle activation, altered movement patterns or not moving at all (Hodges and Tucker, 2011). Central sensitization to pain describes an increased responsiveness to pain signals in the central nervous system to normal or subthreshold afferent input, which can result in hypersensitivity to pain signals and can alter pain perception. This change in the interpretation of pain can influence motor planning in the brain. In terms of MTrPs, latent MTrPs can evolve into active MTrPs (Hong & Simons, 1998), resulting in a constant nociceptive input into the dorsal horn and can develop into peripheral and central sensitization (Mense, 2010; Fernández-de-Las-Peñas & Dommerholt, 2014). Peripheral neuromuscular modifications due to chronic joint pain/disease can result in muscle dysfunction causing weakness, atrophy, impaired proprioception, as well as protective nociceptive reflexes (inhibition/guarding).

Research on sensorimotor dysfunction related to MTrPs is emerging. MTrPs change activity within the muscle itself and between muscles. Examination of the muscle itself demonstrates that not all parts of the muscle are equally prone to the development of MTrPs (primary and secondary MTrPs) (Simons & Travell, 1998) and even latent MTrPs result in muscle stiffness (Sánchez-Infante et al., 2021). Nociceptive activity in active and latent MTrPs can influence motor activity and the sensitivity of other MTrPs in distant muscles at similar segmental levels (Heish et al., 2014; Srbely et al., 2010, Carlson et al., 1993; Fernández-Carnero et al., 2010). Adaptation to motor function expressed as suboptimal timing of muscle activation patterns has been experimentally observed in people with MTrPs. Deep neck flexors are inhibited with neck pain (Jull et al., 2004; Falla et al., 2004). The impairment manifests as poor coordination of the neck musculature with decreased activation of the deep musculature

compared to the superficial neck musculature. Experimental results measuring the cervical flexor musculature with a low load cranial flexion task confirmed these findings with an increased EMG amplitude of superficial neck musculature including sternocleidomastoid (Jull et al., 2004) and anterior scalene (Falla et al., 2004) and in a rapid arm movement task there was decreased activation of deep and superficial neck flexors (Falla et al., 2004). Pain-free muscle activation patterns of upward rotation in the shoulder girdle were explored by studying latent MTrPs in the UT. Lucas and colleagues found muscle activation patterns were altered in two conditions, unloaded (2004) and loaded (2010). Lucas and colleagues' studies employed surface EMG to measure the timing onset of UT, lower trapezius, serratus anterior, infraspinatus and middle deltoid and found the healthy control group exhibited stable muscle activation patterns compared to the variable patterns in latent MTrP group; treatment to the latent MTrPs with DN combined with passive stretch resolved these abnormal muscle activation patterns. In general, sub-optimal muscle activation strategies result in increased energy expenditure and altered joint mechanics with the predisposition to overuse injuries and recurrence (Jull et al., 2019).

Research confirms the sensorimotor dysfunction exists and treatment may reduce recurrence, however more support is needed for the efficacy for the treatment of DN MTrPs on motor performance. The Fitts' task has been successfully adapted to a head turning task to study cervical motor performance using cervical joint manipulation (Passmore et al., 2007). Similar mechanisms are proposed for the manual therapies, including manipulation and dry needling (Hsuesh et al., 1998; Fernàndez-de-la-Peñas et al., 2005), making the motor performance outcome measure, the Fitts' task, a natural choice. The aim of this experiment is

to demonstrate the efficacy of DN latent MTrPs on motor performance measured by a Fitts' head turning task in people with recurrent neck pain.

Literature Review

Myofascial pain

Musculoskeletal pain refers to pain in the muscles, bones, ligaments, tendons, and nerves. Myofascial pain syndrome (MPS) is a complex of sensory, motor, and autonomic symptoms associated with myofascial trigger points (Srbely, 2010). Myofascial trigger points are prevalent in various musculoskeletal pain populations (Lluch et al., 2015) and are proposed to be the origin of myofascial pain (Gerwin et al., 2004). The treatment of pain is necessary to client-centred care in physiotherapy. It follows that to understand the treatment of pain, an interventional model that identifies and treats the appropriate mechanism of pain will lead to positive outcomes (Chimenti et al., 2018).

Myofascial Trigger points (MTrPs)

Definition

A MTrP is “a hyper-irritable spot in a taut band of a skeletal muscle that is painful on compression, stretch, overload or contraction of the tissue, which usually responds with a referred pain that is perceived distant from the spot” (Travell & Simons in Donnelly, 2019). These focal, contracted bands have the potential to induce peripheral and central sensitization with the presentation of tenderness, referred pain, allodynia, and hyperalgesia (Fernandez-de-las-Penas & Dommerholt, 2014; Gerwin, 2016; Lluch et al., 2015).

Clinical features of Active and Latent MTrPs

MTrPs can be classified into two categories: active and latent. A taut band of musculature is the primary feature of a MTrP. An overlapping anatomical position of active and latent MTrPs suggests latent MTrPs may be a pre-curser to active MTrPs (Babero et al., 2013). The excitability of the MTrP appears to be on a continuum where latent MTrPs can transition into active MTrPs depending on their level of irritability (Hong & Simons, 1998). Active MTrPs exhibit spontaneous pain that refers or "triggers" pain when stimulated, whereas latent MTrPs are only painful with manual stimulation but they can provide nociceptive input (Dommerholt, 2011). It has been proposed that latent MTrPs may be connected to the dorsal horn via ineffective synapses (Mense, 2008) and when these synapses are activated with excitation of muscle nociceptors referred pain from the muscle follows. Mechanical stimulation of the MTrP provokes a LTR, which is thought to be a single muscle fiber action potential that aids in the confirmation of the MTrP clinically (Hong & Simons, 1998).

The mechanism of the development of the taut band is altered activity in the motor endplate. Both active and latent MTrPs exhibit a prevalence of end-plate noise (likely from an increased concentration of acetylcholine in the synaptic cleft), known as spontaneous electrical activity, which can be measured by electromyographic recordings (Kuan et al., 2007). Local myofascial pain results in a release of substances from the damaged muscle creating an "acidic milieu". These biochemical substances, including adenosine triphosphate, bradykinin, substance P and serotonin, collected with a micro-dialysis needle have higher concentrations at active and latent MTrPs compared to normal muscle tissue (Shah et al., 2005).

Active MTrPs can cause sensory symptoms and motor dysfunction. Motor dysfunction can be characterized by a constant discrete hardness within the muscle and sensory dysfunction is characterized by an atypical response to pain (Gerwin et al., 2004). Altered motor function presents as muscle stiffness with associated restricted range of motion, weakness with decreased work tolerance and loss of coordination (Cao et al., 2021). Autonomic disturbances include vasodilation, vasoconstriction, sudomotor and pilomotor response (Cao et al., 2021). Given that latent MTrPs are not spontaneously painful, finding an association of motor dysfunction with latent MTrPs is of interest, since the typical driver of motor deficits is pain. Motor deficits in latent MTrPs manifest as stiffness with associated decreased range of movement, altered patterns of muscle recruitment (Lucas et al., 2010), facilitation of referred effects (muscle cramps) (Ge et al., 2008, 2014), and altered activity of distant muscles (Fernández-Carnero et al., 2010).

Muscle Pain Models

The Integrated Hypothesis, the most prominent model for myofascial trigger point formation, proposes a self-sustaining pain-spasm-pain cycle (Travell and Simons, 1998). MTrPs are proposed to begin with a local injury to the musculotendinous unit. The essential features of this model are an abnormal increase in the production and release of acetylcholine, with resulting sarcomere shortening and secretion of sensitizing substances. Following a local acute or chronic overload of a muscle, an increase in motor end plate activity results in persistent release of acetylcholine and sustained depolarization of the post-junctional membrane of that muscle fiber. This continuous release combined with inadequate uptake of calcium ions from the sarcoplasmic reticulum results in sustained shortening of sarcomeres (increased muscle

fiber tension or taut band). The spasm results in hypoxia creating an “energy crisis” from the release of vasoactive and allogenic substances, which results in a deficit in the production of adenosine triphosphate and failed re-uptake of calcium ions into the sarcoplasmic reticulum, thus continuing the contractures of sarcomeres and ultimately creating a self-sustaining vicious cycle of pain-spasm-pain (Chou & Lin, 2012; Giamberardino et al., 2011). An expansion of the Integrated hypothesis by Gerwin, Dommerholt and Shah (2004) further refines the energy crisis and expands the model to include more muscle pathophysiology, specifically muscle fiber injury, neurogenic inflammation, and central sensitization.

Myofascial pain models began with a pain-spasm-pain models (Mandel, 1982; Simons and Travell, 1998; Gunn, 1978). Pain-spasm-pain models are now considered limited because muscle pain can inhibit rather than facilitate alpha and gamma motor neuron drive (Le Pera et al., 2001; Mense & Skeppar, 1991). There has been a theoretical shift away from the concept that muscle hyperactivity maintains pain, to muscle dysfunction, that acts as a protective adaptation rather than the cause of pain. Lund’s (1991) Pain Adaptation Model proposed muscle activity of the agonist is reduced with a small increase in the level of activity in the antagonist with the consequences of changes in force production, range of movement and velocity of movement. However, this model cannot account for co-contraction of agonists and antagonists in pain or the concept that motor neuron activity is not always uniform (Tucker et al., 2009).

A new model emerged, the Motor Adaptation Model (Hodges & Tucker, 2011), that proposes the nervous system adjusts movement patterns in response to pain and can account for excitation and inhibition in the motor system. Neuromuscular adaptations include

redistribution of activity within and between muscles (Hodges, 2011). The clinical presentation of pain and movement dysfunctions are variable. For example, re-current neck pain can produce an adaptive change of generalized stiffening (Meisingset et al., 2015), where the person splints or braces their neck to protect it from further injury or threat of injury (Hodges et al., 2013). Symptoms include limited range of motion, postural adaptations with difficulty in adjusting to movement dynamically. Gross muscle stiffening or bracing can cause motor facilitation in both agonist and antagonist muscle groups (Martin et al., 2008), though the firing of the motor neurons and the degree of activity can vary depending on the muscles involved in the bracing. Stiffening on the level of the muscle itself has been proposed as a functional adaptation to pain, where a MTrP effectively shortens the muscle due to the increasing overlap of actin and myosin resulting in decreased range of movement (Donnally, 2019). Other neuromuscular adaptations may result from muscle inhibition resulting in compromised kinematic movement with decreases in amplitude or velocity (Svensson et al., 1997; Tsang et al., 2014), decreased muscle activity as a strategy for pain avoidance (Vlaeyen et al., 2000) and altered muscle recruitment patterns. Altered recruitment patterns have been associated with pain in the cervical spine and shoulder girdle (Szeto et al., 2005; Elert et al., 2001; Falla et al., 2007; Falla & Farina 2007; Mork & Westgaard, 2006).

Adaptive changes in the neuromuscular system can reduce pain in the short term, however in the long term can become maladaptive. Longer duration adaptations can cause increases in muscle load from co-contraction, increased risk of further injury due to muscle inhibition, and decreased variability of movement. One of the consequences of a dysfunctional pain responses is muscle over-use due to a change in the distribution of work (Jull et al., 2019;

Hodges & Tucker, 2011). Abnormal tissue loading in the muscle can potentially shift the pain mechanism from the original injury to an ongoing mechanical load provoking pain (O'Sullivan, 2005). This peripherally driven nociceptor sensitization can potentially lead to nociplastic changes in the CNS (Mense, 2008).

Nociplastic pain

Nociplastic pain is "pain that arises from altered nociception despite no clear evidence of actual or threatened tissue damage causing the activation of peripheral nociceptors or evidence for disease or lesion of the somatosensory system causing the pain" (Loeser, 2011). Nociplastic pain arises from disturbance of nociception processing resulting in a sensitization of the central nervous system (CNS). CNS sensitization presents with an increased excitability to normal input and/or decreased inhibition of nociceptive neurons, as well as spontaneous discharges and increases in the size of the receptive field (Cohen & Mao, 2014). Clinically, sensitization can be inferred by assessing for hyperalgesia and/or allodynia. Hyperalgesia being an "increased pain from a stimulus that normally provokes pain" (Loeser, 2011). An increase in synaptic efficacy and decrease in inhibition of pain effectively enhances the pain response regarding its' amplitude and duration. Allodynia is defined as "pain due to a stimulus that does not normally provoke pain" (Loeser, 2011). Here, the expansion of the receptive field or gain in neurons in the pain pathway in the CNS means pain can be generated from a stimulus that does not normally produce pain, for example, "touch, light pressure, or moderate cold or warmth evoke pain" (Loeser, 2011). Nociplastic pain, typically described as persistent pain, can present with a combination of nociceptive and/or nociplastic mechanisms. The symptoms tend to be more diffuse and can include widespread pain, fatigue, sleep dysfunction and cognitive

disturbance (Chementi et al., 2018). However, pain can also be isolated, caused by altered CNS processing resulting in referred pain, also known as, secondary hyperalgesia (Woolf, 2011).

Proposed Pathophysiology of Secondary MTrPs

MTrPs have been found in muscles without acute trauma or overload (Hong, 2002). These secondary MTrPs are hypothesized to be "discrete secondary peripheral neurogenic manifestations of central sensitization caused by a primary pathology within the common neuromeric field" (Srbley, 2010). In this neurogenic hypothesis, persistent nociception from any primary pathology (somatic or visceral) has the potential to cause central sensitization and subsequently neurogenic inflammation modulated by the spinal cord, brain, and descending modulation systems. It is thought that "neurogenically mediated inflammation leads to the discharge of inflammatory mediators and neuropeptides, [which can] trigger a cascade of inflammatory events leading to the sensitization of peripheral nociceptors" (Srbley, 2010). Neuropathy provides the mechanisms to explain ectopic discharge. These abnormal signals are interpreted by the brain as pain, even though there may not be any actual tissue damage. Various experiments cite evidence of MTrP resolution occurring with the resolution of the primary pathology (Jarrell, 2004; Tsai et al, 1999).

Examination and Diagnosis of MTrPs

Evidence for the clinical phenomena of MTrPs

The mechanism for the formation of MTrPs is unknown and the lack of a gold standard for clinical identification of MTrPs invites skepticism, however empirical evidence continues to

grow and support this phenomenon. A consensus in the literature supports MTrPs as a clinical entity associated with musculoskeletal pain conditions with significant evidence for neck pain (Lluch et al., 2015). Animal experiments of acute muscle trauma have successfully modeled the pathophysiological development of MTrPs (Hong & Torigoe, 1994; Margalef et al., 2019). MTrPs exhibit distinct imaging, vascular, biochemical and electrophysiological characteristics (Chiarotto et al., 2016). Ultrasound studies can visualize differences in local tissue density with an abnormal reduction in echoes and relative ischemia (Turo et al., 2012; Sikdar et al., 2009). Sonoelastography can locate and distinguish between normal muscle, active MTrPs and latent MTrPs (Ballyns et al., 2011). Magnetic resonance elastography studies visualizing MTrPs suggest "the stiffness of a taut band may be 50% greater than that of the surrounding muscle" (Chen et al., 2008). Biochemical investigations found the extracellular fluid of the MTrP to be acidic (pH of 4 or 5) with an accumulation of neurotransmitters and cytokines (Shah et al., 2005). These substances are associated with persistent pain, inflammation and MTrP sensitization. Electromyographic studies confirm MTrPs have a unique spontaneous electrical activity (SEA) or end plate noise that is described as persistent, fast, low-amplitude activity with less frequent, high-amplitude discharges (Hong & Simons, 1998; Kuan et al., 2007). These biomarkers help to validate MTrPs as a clinical entity and support from a recent systematic review confirms soft tissue imaging provides various reference standards for diagnostic treatment and assessment of MTrPs (Mazza et al., 2021).

Diagnostic criteria for the identification of MTrPs

Clinically, there is no "gold standard" for the evaluation of MTrPs – physical examination using manual palpation is the current standard for assessment and diagnosis. Clinical

identification of MTrPs is complex; based not only on skilled palpation, but also keen observation and patient response. A consensus on the diagnostic criteria of a MTrP's offers a starting point for accurately defining, locating and treatment purposes. Tough et al.'s literature review (2007) found four most frequently used diagnostic criteria in research were a tender spot in the taut band, patient pain recognition, predicted pattern of referred pain, and local twitch response (LTR). The LTR is associated with a brief and sudden contraction in a taut band of muscle that offers an objective sign to aid in the confirmation of the diagnosis of MPS (Hong, 1994). A recent systematic review found the characteristics of MTrPs to be spot tenderness (described as a hypersensitive spot/nodule, taut band, or tender spot in a taut band), referred pain, LTR, pain recognition, limited range of motion, and jump sign; and the most frequent features of MTrPs were spot tenderness, referred pain and LTR (Li et al., 2020). Myofascial pain expert consensus found a preliminary set of diagnostic criteria for MPS to be a "tender spot causing local pain and recognition of symptoms upon palpation of tender spot" combined with at least three of the following symptoms "muscle stiffness/spasm, limited range of motion, pain worsens with stress and palpation of taut band +/- nodule with tender spot" (Rivers et al., 2015). A Delphi study narrowed the scope from MPS to MTrPs specifically and found diagnosis required a minimum of two of the following: a taut band, a hypersensitive spot, and referred pain (Fernández-de-Las-Peñas & Dommerholt, 2018).

Palpation of MTrPs: Reliability and Validity

There are many potential challenges palpation must overcome to enable a valid and reliable diagnosis including variances in the rate and application of pressure, depth of the muscle (for example, superficial and deep), location of the muscle and agreement between and

within examiners (Rathbone et al. 2017). The methodological quality of reliability studies for the palpation of MTrPs has been generally poor, however evidence with higher quality clinical trials can be found to support the inter-rater reliability of manual palpation of MTrPs (Gerwin et al.,1997; Lucas et al., 2009; Myburgh et al., 2008). A case-control study identifying the presence or absence of MTrPs in the upper quadrant found substantial interrater reliability between two examiners suggesting the validity of clinical criteria and the reliability in the diagnosis of MPS (Mayoral del Moral et al., 2018). Moving forward, methods to improve methodological quality and increased inter-rater agreement between therapists are operationalizing diagnostic criteria, palpation protocols and including palpation training (Gerwin et al., 1997). Rathbone's systematic review (2017) found the most reliable palpation criteria were non-specific in nature "pain recognition and local tenderness" and the more specific anatomical/physiological criteria supporting construct validity of "pain referral, LTR and tender nodule in a taut band" were the least reliable. To rectify this lack of diagnosis specificity researchers can combine palpation with pressure algometer measures, range of movement and documentation of the response to treatment regarding the LTR to support the diagnosis. Pain pressure thresholds (PPT) offer a quantifiable measure of tenderness to confirm MTrPs and thus aid in confirming the diagnosis of MPS.

Palpation Protocol

The objective of palpation is to, first, identify taut bands of musculature, and second, to identify hardened contracted bands within the muscle. Pincer palpation is utilized if the muscle can be grasped between the thumb and long finger pads allowing the muscle to be rolled. Flat palpation is implemented when the muscles cannot be grasped between fingers or if there is no

bony prominence available for a backdrop to compress the taut bands against. The muscle should be palpated in a neutral or resting position, perpendicular to the direction of muscle fibres until the area of greatest tenderness is located within the taut band of muscle without the patient's input. When a gentle to moderate pressure is applied for 5-10 seconds, the patient is asked to report on pain associated with palpation including jump sign (when startled by the pain response), local tenderness, local twitch response and, if sufficiently hyperirritable, referred pain (presence of pain at a distance from the spot) (Donnelly, 2019).

Location of MTrPs

The location of MTrPs is within a taut band of musculature and is synonymous with a "trigger point region" where multiple sensitive loci reside within the trigger point (Hong, 1994). The MTrP's location is associated with the motor end plate or innervation zone, where "the α-motor neuron divides into a number of branches and synapses onto target muscle fibers" (Barbero et al., 2013). MTrPs have dysfunctional motor end plates, with electrophysiological and biochemical changes (Shah et al., 2005). In muscles with parallel fibers the innervation zone is in the mid-muscle belly (Simons et al., 2002; Barbero et al., 2013). Physiologically, the motor point has a high density of neuromuscular junctions and is referred to as the innervation zone or end plate zone (Franz et al., 2018). The morphological nerve entry point in the muscle is distinct from the functional motor point (Franz et al., 2018). To improve neurophysiological function of a muscle using a mechanical intervention, such as dry needling, accurate needle position that targets an area with a high density of motor end plates would expect to improve effectiveness.

Location and Palpation of Upper Trapezius (UT)

For the purposes of this research latent MTrPs in the UT are the focus. The high frequency of latent MTrPs in the UT (78%) combined with their association with motor dysfunction in the neck and shoulder girdle provides clinical relevance for further study (Lucas et al., 2008). Anatomically UT attaches to external occipital protuberance, medial one third of the superior nuchal line, ligamentum nuchae and spinous process of the seventh cervical vertebrae (Kendall et al., 1983). The ventral rami of C3, C4 innervates the sensory function of the trapezius. The accessory nerve, cranial nerve XI, innervates the motor function. UT is a prime mover in extension, lateral flexion, and rotation (to the contralateral side) of the cervical spine. The superficial position of UT anatomically enables an increased reliability when palpating (Mayoral del Moral et al., 2017). Visualization of an UT MTrP using ultrasound imaging reports the localized stiff nodule to be 0.16+/- 0.11cm^2 and its' elliptical shape can be reasonably palpated (Sikdar et al., 2009). Graphical representations and mapping of MTrPs and innervation zone in the UT are well defined and correlate to the original criteria by Simon's and Travell (Barbero et al., 2013). However, though UT MTrP are in the proximity of the innervation zone, they do not overlap and a mean distance of 10.4 +/- 5.8mm separates them (Barbero et al., 2013). Anatomical mapping describes four quadrants that divide the area from the seventh cervical vertebrae to the acromial angle. Innervation zones are located approximately mid-way between the second and third quadrants and MTrPs were in the third quadrant. The UT exhibits the highest reproducibility when applying the diagnostic criteria of MTrP (Levoska et al., 1993; Gerwin et al., 1997; Myburgh et al., 2011). Meta-analysis on the inter-rater agreement for the palpation of UT found K = 0.602 (95% CI 0.348-0.855), p = 0.006, I^2 = 76% and the author

suggests that even though the value of k is moderate, a large confidence interval remains suggesting caution with interpretation as there is a large variance between raters) (Rathborn et al, 2017).

Relevant anatomical landmarks (acromion, C7 spinous process, the motor points, Travell and Simons' MTrP map location), as well as an examination protocol for UT were reviewed (Myburgh et al., 2008). The physiotherapist/examiner must be attentive to boney landmarks, tissue density and temperature. Minimal palpation pressure is more effective for palpating MTrPs, causes less tissue irritation and limits the potential for a treatment effect from heavy handed palpation. Mapped MTrPs are very similar to the location described by Travell and Simons, and anatomically, the UT MTrPs were consistently found slightly medial to the muscle's midpoint between the acromion and the C7 spinous process (Barbero et al, 2012). MTrPs and taut bands tend to form over the motor point or zone of innervation in the mid-belly portion of the muscle, where there is low electrical resistance (Gunn, 1996). The motor point offers a predictable, relatively defined starting point for the palpation of MTrPs and confirmed as localized tender point in a taut band.

Interventions

Dry Needling (DN) Mechanism

Mechanical, neurophysiological, and biochemical mechanisms have been proposed for deactivating MTrPs with dry needling (DN). Clinical features of MTrPs include the development of taut bands that result in capillary constriction, local ischemia, and tissue hypoxia (Caignie, 2013). One of the proposed targets of dry needling is dysfunctional motor units (Dommerholt,

2011; Caignie, 2013). The mechanical stimulation of DN elicits a LTR and is hypothesized to reduce the excess of acetylcholine at the motor end plate area of the MTrP and decreases spontaneous electrical activity (Chen et al., 2001; Hsieh et al, 2012), as well, reduce the overlap of actin-myosin filament overlap. It has also been proposed that the mechanical stimulation of the needle activates Aβ-nerve fibers, initiating segmental inhibition via the gate control theory of pain (Baldry, 2005). A neurophysiological effect is hypothesized by reducing peripheral and central sensitization by "removing the source of peripheral nociception," the MTrP, in turn, reducing transmission into the dorsal horn and activating descending inhibitory pain pathways (Cagnie, 2013; Chou et al., 2012). Animal models have explored remote analgesic effect by dry needling a distal muscle unilaterally and assessing changes in the levels of pain-related peptides, Substance P, in the dorsal horn of the corresponding spinal segment bilaterally. Results demonstrate that immediately after DN a peripheral muscle there were decreases in Substance P in the periphery and bilateral spinal superficial laminae (Hsieh et al., 2014). Another animal study focusing on blood flow found an increase in "hypoxic-responsive" proteins that potentially improve the circulation in muscles containing MTrPs post DN (Hsieh et al., 2012). Dry needling at the MTrPs have been shown to regulate biochemical compounds (β-endorphin, substance P, TNF-α, COX-2, HIF-1α, iNOS, and VEGF) associated with pain, inflammation, and hypoxia in a dose-dependent manner (Hsieh et al., 2012; Hsieh et al., 2014; Shah et al., 2005). The mechanisms of dry needling are complex and likely related to a combination of immune, hormonal, and nervous system interactions (Chou et al., 2012).

DN Definition and Technique

Dry needling is the insertion of a fine filiform acupuncture needle into the MTrP with the goal of eliciting a local twitch response (LTR). The LTR is associated with a greater success in deactivation of the MTrP (Hong, 1994). The needle insertion technique utilizes a quick tap to bypass A-Delta nociception fibers. If skin resistance or sharpness occurs, then the needle direction is changed slightly or withdrawn. The physiotherapist stabilizes the patient's tissue with their palpation hand and the other hand holds the needle between the thumb and index finger. The needle tip is held with its' tip slightly withdrawn from the patient's skin within the introducer sheath, then the index finger firmly taps the needle through skin, the tube is removed, and the needle is advanced into the tissue. Hong (2006) describes a "fast in, fast out" method of needling of a MTrP precisely located by palpation. The needle is intended to initially penetrate the MTrP, followed by the retraction of the needle without withdrawing it from the skin, then plunging again with the desired response of a muscle twitch (LTR) or "grabbing sensation" (spasm) at the needle tip. The treatment response is often associated with a deep aching sensation. Once the first LTR is produced, the needle is repeatedly moved up and down, perpendicular to the muscle, to get additional LTRs. Historically, the needling continues until as many LTRs as possible are elicited to ensure as many of the sensitive loci in the muscle are encountered and deactivated (Hong, 2006). Current research suggests three or four twitch responses achieve a positive outcome, however six LTR and/or needling to the exhaustion of the muscle produces superior, clinically important differences for range of movement and pain outcomes as compared with not eliciting LTRs (Fernández-Carnero et al., 2017). For the UT MTrP, a cross-fiber pincer palpation is utilized and held firmly to lift the muscle away from

underlying cervical structures and the apex of the lung and the needle is directed slightly caudally, posterior–anterior direction (Gunn,1996; Donnelly, 2019).

Sham procedure

There is a consensus in the literature that control acupuncture, sham/minimal acupuncture, or a non-penetrating device, produce specific effects, and cannot be interpreted as inert (Lee et al., 2023; Zhang et al., 2015). The act of DN has two components: the skin puncture and a vertical “in and out” movement of the needle within the muscle. This DN experiment includes a significant amount of tissue manipulation including initial palpation of the MTrP for inclusion/exclusion into the study, for marking the MTrPs for pressure algometry measures, as well as manipulation of the muscle during the intervention. It is important to note that the intensity of DN differs from that of acupuncture, as muscle is the target tissue is generally deeper than the superficial points of acupuncture, so effective blinding requires researchers to simulate needle insertion and manipulation techniques that are used in the active intervention (Braithwaite et al., 2019).

The types of controls in DN RCTs are sham, placebo, pseudo-stimulation (TENs or guide tube), other therapies, or no treatment (waitlist). Penetrating shams are defined as skin penetration using an acupuncture needle at a shallow depth or at a non-MTrP location. Placebo acupuncture is non-penetrating using placebo acupuncture devices or non-penetrating shams. Heterogeneity in non-penetrating sham RCTs makes it difficult for researchers to reach a consensus on the best placebo/sham intervention.

Penetrating needles have a physiologic effect on pain. Though the depth or location of the needle insertion may impact the effectiveness, we know needle penetration itself has some

therapeutic effect on pain (Birch et al., 2006; Lund et al., 2006). An acupuncture RCT found the increased stimulation required to achieve the DeQi sensation (associated with acupuncture) resulted in the most pronounced increase in skin and muscle blood flow, interestingly, no increase in blood flow was found with superficial needling (Sandberg et al., 2003). Lundeberg and colleague (2011) found there was no difference in efficacy between superficial needling and acupuncture, which suggests a strong placebo effect in needling.

In terms of the physiological effect of the needle, we must consider that both a blunted needle and shallow skin penetration with an acupuncture needle will potentially cause pain and the difference in the effect size may come down to the effect of the puncture itself. In terms of effect size, a meta-analysis of individual patient data of acupuncture randomized control trials for pain using non-penetrating needle controls observed larger effect sizes than those using penetrating needle sham control (MacPhearson et al., 2014). This observation highlights that there is a mechanism or treatment effect with skin penetration. Thus, if the goal is to test the effectiveness of DN beyond the effect of the puncture or perceived puncture, the inclusion of the puncture with the sham control allows us to further isolate the effects of needling the muscle. In other words, effect size may narrow with more afferent input into the control intervention, enabling the answer to the critical question of the effect of dry needling on the chosen outcome measures.

In terms of blinding, a systematic review found participants were unable to decipher if a needle penetrated the skin or not; participants appeared to guess they were a recipient of a verum treatment when in fact they received a sham treatment (Moroz et al., 2013). The most recent systematic review and meta-analysis found non-penetrating and

penetrating sham groups had almost equally effective blinding (Braithwaite et al., 2019). Braithwaite and colleagues (2019) recent systematic review contradicts Moroz and colleagues (2013) previous review of acupuncture and DN trials that reported most sham devices (except for custom devices) provided an effective blind, however penetrating shams provide the most effective blind. Braithwaite and colleagues suggest this discrepancy could be a result of a smaller number of group comparisons in their review (n=15 versus n= 54).

Finally, two recent Delphi surveys suggest the experience of the entire intervention is more important for blinding than the replication of tactile sensations (Braithwaite et al., 2020). Also of note, is that the expectation of a therapeutic effect can have neurophysiological effects of placebo analgesic whether the participant has either a verum or a sham intervention (Lundeberg et al., 2011).

Blinding includes indirect psychological effects of the environment, as well as a mechanistic control of the intervention itself. Given that DN appears to have multiple mechanisms of action, and each mechanism is distinct from palpation and skin puncture, enables us to include all relevant stimuli up to insertion into the muscle. For these reasons, in this experiment, a penetrating sham intervention will be compared to a verum intervention.

Motor Performance Outcome Measure

Fitts' Head Turning Task

Fitts' Law is a robust mathematical model used in motor control research to study human movement and performance (Beamish et al., 2006). The study of goal directed movement and the time to complete the movement was pioneered by Woodworth in 1899.

With the complexity of a reciprocal arm aiming task, the relationship between speed and accuracy in movement was further developed by psychologist Paul Fitts (1954). Fitts and Peterson (1964) further refined the task to single-shot or discrete pointing tasks. The premise of Fitts Law is that pre-planned movement is flexible enough to adapt to environmental demands. Fitts Law describes the linear relationship between the time required to complete a discrete movement and the distance to and the width of the target. For motor control work, this law provides a valuable tool for understanding and predicting movement in the context of pointing tasks (Equation 1: Formula for Fitts' Law).

Equation 1: Formula for Fitts' law

$$\mathrm{MT} = a + b\left[\mathrm{Log}_2\left(2A/W\right)\right]$$

MT: is the total movement time,
constant a is the intercept and represents MT when the ID is zero,
constant b is the slope and represents change in the ID,
A represents the distance between the targets,
W represents the widths of the targets.

The application of Fitts' Law in motor control research comes from its use in calculating an index of difficulty (ID). The ID reliably describes the difficulty of a task and is calculated with this logarithmic term (Formula 2: ID).

Equation 2: Index of Difficulty (ID)

$$ID = \log_2\left(\frac{2A}{W}\right)$$

ID: index of difficulty,
A is the amplitude/distance to the target,
W is the width of the target,
Measured in bits.

Fitts' Law is utilized to index the speed and accuracy trade off (Fitts,1954, Fitts & Peterson, 1964), where the speed of a rapid goal-directed movement is limited by the accuracy

demands placed on the movement. The prediction of Fitts' law is that as the difficulty of the task increases (distance to the target increases or the size of the target decreases) the movement time required to reach the target increases. This implies participants will have to adopt a compromise between speed and accuracy to achieve the target. In terms of motor control, the consequence of the relationship between speed and accuracy is increased motor planning and afferent feedback as the accuracy demands increase. Increased motor planning and feedback demands result in slower MTs in response to the need for accuracy in the target acquisition. The Fitts' task offers a quantifiable way of increasing or decreasing the task difficulty enabling the testing of discrete goal directed aiming tasks.

The Fitts' task has been successfully adapted to quantify the movement of the head in a turning task (Descarreaux et al., 2010, Passmore et al., 2007, Passmore et al., 2010) that is employed in the current study. Passmore and colleagues (2007) developed a discrete aiming task for cervical movement using a head mouse to simulate the Fitts' movement paradigm with the goal of describing neuromuscular differences in head control between a young and old population. The findings suggest age related changes with a decrease in cervical range of motion, increased movement time and variability in performance. These findings support their hypothesis of age-related deterioration of central processing, planning and/or perceptual mechanisms. Passmore and colleagues (2010) conducted a single-blinded study on 15 asymptomatic (hypomobile at C1/C2) participants to assess the effect of spinal manipulation on ROM and sensorimotor outcomes utilizing the Fitts' task outcomes. This test-retest study design found significant increases in active cervical range of motion and significant decreases in movement times post spinal manipulation. Descarreaux, Passmore and Cantin (2010)

conducted a follow up study comparing chronic neck pain to a healthy population with the outcomes of movement time with the addition of kinematic variables (acceleration and deceleration) and movement accuracy to identify neuromuscular system impairments related to cervical spine movement and function. The chronic neck pain population (compared to the healthy population) exhibited a significant increase in movement time, an increase the deceleration phase duration (for tasks of increased difficulty i.e.: for the small target/large movement amplitude) without decreases in accuracy or increases in variability, which suggests that the chronic neck pain population have significantly decreased motor performance.

The Fitts' task validity is well established with a strong correlation between the index of difficulty and movement times in pointing tasks (Plamondon & Alimi, 1997). The Fitts' task is suitable for pre-post intervention studies due to the resistance to learning effects (Beamish et al., 2006; Schmidt & Lee, 2011 in Aloraini et al., 2019). A recent systematic review assessing sensorimotor control comparing neck pain to normal populations reported increased movement time and increased errors during a head aiming task with a strong level of evidence, though the findings for reaction time, peak velocity and peak acceleration had no or very limited evidence due to the high variability in the task and the outcome variables studied (Franov et al., 2022). The Fitts' task has been shown to be a valuable methodological approach for assessing on sensorimotor outcomes.

Research Statements

Rationale

To date, there are limited high quality studies conducted on the effect of dry needling on function or motor performance, though research is emerging (Martín-Rodríguez et al., 2019). Typically, functional outcomes are measured with the Neck Disability Index (Lew et al., 2021). Dry needling efficacy has proven treatment effectiveness when measured against sham interventions and other physiotherapy interventions (Gattie et al., 2017). The effect of dry needling on spasticity/muscle tone has been established in a stroke population, though functional outcomes measured by questionnaire were inconclusive (Fernández-de-las-Peñas et al., 2021). The effect of latent MTrPs on muscle activation patterns and performance in the shoulder girdle have been studied from a mechanistic perspective, but, not from a treatment efficacy perspective (Ge et al.,2008, Ge et al., 2014; Lucas et al., 2004; Lucas et al., 2008). Given that pain is associated with movement and motor adaptation, the relationship between active MTrPs and motor effects is difficult to establish. Studying pain-free or latent MTrPs using an objective performance measure enables the relationship between MTrPs and motor control to be examined. The aim of this randomized clinical trial is to determine the immediate efficacy of a DN compared to a sham procedure, by means of a single treatment session, to the latent MTrPs of the UT, with the primary outcome measurement of motor performance measured by the Fitt's Task. Secondary clinical outcomes include range of movement, along with the sensory components of pressure pain thresholds and a VAS. We hypothesize that participants receiving DN will exhibit immediate improved motor performance than those receiving sham needling.

Purpose

The purpose of this study is to investigate the effect of dry needling versus a sham procedure on the upper trapezius myofascial trigger points on motor performance, range of movement, pain pressure thresholds and pain intensity immediately after one treatment session in individuals with latent myofascial trigger points and a recurrent history of mechanical neck pain.

Objectives

1. To determine whether dry needling upper trapezius results in improved motor control measured by the Fitts Task when compared to sham needling.
2. To determine whether dry needling upper trapezius results in improved range of motion measured by CROM when compared to sham needling.
3. To determine whether dry needling results in a reduction of pain pressure thresholds measured by pressure algometry when compared to sham needling.
4. To determine whether dry needling results in a change in pain measured by a visual analogue scale when compared to sham needling.
5. To determine whether dry needling results in a change in functional ability measured by the Neck Disability Index.

Research Hypothesis

Dry needling will be an effective intervention for motor performance when compared to sham dry needling measured by an improvement in Fitt's task, range of motion, pain pressure thresholds, pain intensity scores in a clinic with individuals with recurrent mechanical neck.

Null hypothesis

There will be no significant difference between the two groups, dry needling treatments and sham dry needling, for the measures of each outcome including Fitt's task, range of movement, pain pressure threshold and pain intensity.

Methodology

This study utilized a randomized, pre/post clinical trial design to measure the immediate effects of DN on motor performance. Approval was obtained from the University of Manitoba Biomedical Research Ethics Board (HS25717) and was registered with clinicaltrials.gov (NCT05846022).

Sampling

The incidence of neck pain increases with age and peaks between the ages of 30 - 45 (Croft et al., 2001). Neuromuscular performance in a Fitts' task diminishes with age due to "musculoskeletal slowing" with possible age-related deterioration of central processing, planning, or perception mechanisms (Passmore et al., 2007). Thus, the demographic pool sampled was 30-45 years old, to capture peak pain, limit the possibility of age-related changes and included both genders to represent a natural clinical population. A sample size power calculation was completed using G*power software based on parameters of an estimated moderate effect size of 0.75 adopted from a doctoral thesis examining the effects of cervical spinal manipulation on movement time (Gelley, 2022). A statistical power of 0.95 (equivalent to a beta = 0.05) and an alpha level of <0.05 were set. A total of thirty-six participants (18 per group) were required and recruited.

Recruitment

Participants were recruited from the local community of Winnipeg with advertising posters placed at the university, in outpatient clinics, exercise gyms, studios and posted on

social media. Outpatient practitioners (including doctors, physiotherapists, chiropractors, massage therapists) were asked help to procure potential participants. A snowball approach for recruitment was utilized once the study commenced. The study was conducted in a motor performance laboratory at the University of Manitoba over seven weeks.

Screening and consent

The outcome assessor screened for the participant's eligibility by telephone, and at this time, provided a study overview, answered questions, and set up an appointment for participation. Nine people did not meet the eligibility criteria and were screened out of the study (six by telephone and three by email) and an additional five people were not included because they chose not to answer the screening questions by email. Personal health information and contact information were used strictly for contact purposes.

Eligibility criteria

Inclusion criteria included experiencing recurrent neck pain with a minimum of one episode of acute neck pain corresponding to the area covered by the UT muscle in the last three months, a minimum of one palpable tender taut band of muscle in the UT, be DN naïve, have normal/corrected vision (as required for the Fitts' task) and be fluent in English. The exclusion criteria included experiencing an acute episode of neck pain that required professional intervention, treatment to the UT or cervical spine in the last 60 days, currently taking pain/nerve medications, presence of upper limb neurological signs or symptoms or any history of pathology, surgery, trauma or accident involving the cervical spine and having general contraindications to needling (including pregnancy, acute trauma, fever or systemic infection

and needle phobia), local contraindications at the site of the needle insertion (including local infection, open wounds, burns, inflammation, cellulitis, and undiagnosed lumps) and any precautions to needling (including history of bacterial endocarditis, heart valve replacement, pace-maker and near joint replacements).

Enrollment protocol

Investigators included a physiotherapist, an assessor and a third investigator to conduct the sample's randomization protocol. The interventions were conducted by a physiotherapist with 10 years of DN experience. All outcome measures were taken by an assessor with relevant experience. On the day of data collection, the physiotherapist greeted the participants, answered any questions, and administered written informed consent.

Latent MTrPs were identified using a palpation protocol previously described by Myburgh and colleagues (2008), which was conducted in a prone position using a pincer grip followed by rolling and compressing the muscle (Figure 1: Palpation and marking of UT MTrP). To confirm the presence of a MTrP, palpation was combined with the following series of yes/no questions:

1. Is this spot unusually painful or sore? (To identify local tenderness)
2. Do you recognize this sensation of pain or soreness as familiar? (To identify familiar pain)
3. Does the pain occur anywhere else from the spot that I am compressing? (To identify referred pain)

The examiner observed and recorded local twitch response, jump sign and/or patient pain recognition and the unilateral or bilateral nature of the MTrPs. The inclusion criteria required

for a latent MTrP was the presence of a taut band and local tenderness (Fernández-de-Las-Peñas & Dommerholt, 2018) and once verified the MTrP was marked, and the participants were enrolled. Participants proceeded to the compiling of demographic information including gender, age, height, weight, and BMI followed by the collection of baseline outcome measures. Experimental sessions lasted between 60-70 minutes.

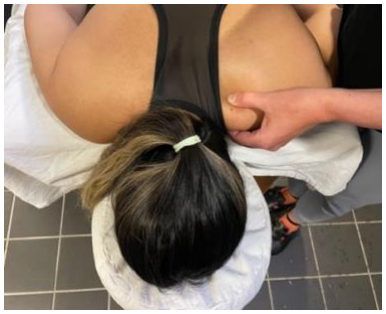


Figure 1: Palpation and marking of UT MTrP

Group Randomization, Allocation and Concealment

Randomization sequence was created using Excel (Microsoft, Redmond, WA, USA) with a 1:1 allocation using random block sizes of 2 and 4 by the third research investigator (Kim and Shin, 2014). The computer randomly chose block size and permutation in the blocks. Allocation was concealed using sequentially numbered, sealed opaque envelopes, which were opened by the physiotherapist immediately prior to the experimental intervention of each participant. Participants and the outcome assessor were blinded to the treatment allocation group.

Interventions DN and sham procedure

A sterile needling technique was implemented; the physiotherapist washed their hands, set-up a clean workspace, exposed the area of treatment, applied gloves, and then applied

alcohol sanitizer to the gloves, swabbed patient's skin with alcohol wipe, opened sterile needle pack, and removed the sheathed needle without touching the needle shaft. The needle insertion technique utilized a quick tap to bypass A-Delta nociception fibers. If skin resistance or sharpness occurred, then the needle direction was changed slightly or withdrawn. To insert the needle the physiotherapist stabilized the patient's UT muscle with the palpation hand. The needle was held between the thumb and second finger to place the needle's introducer sheath onto the patient's skin with needle tip slightly withdrawn. Then the index finger firmly tapped the needle through skin and the introducer sheath was removed and then the needle was advanced into the tissue. The needle was disposed if the needle shaft touched anything other than the patient's subcutaneous tissue. Used needles and any contaminated material were disposed of in a sharp's container.

A single use 30-gauge monofilament needle was used to perform the needling intervention, which utilized a piston or "fast-in and fast-out" technique (Hong, 1994). The goal for dosage was to achieve up to six LTR to ensure the detection of as many UT's MTrPs as possible (Hong, 2006), which yielded superior clinically important differences for range of movement and pain outcomes when compared to not eliciting LTRs (Fernández-Carnero et al., 2017). The sham intervention utilized the same type of needle as the DN intervention, though the insertion was brief, and the needle's removal was followed by repetitive pressure with the guide tube to mimic the piston action of DN.

Clinical Outcome Measures

Clinical and motor performance outcome measures were recorded pre- and post-intervention, followed by a questionnaire at one week post intervention.

Visual Analogue Scale (VAS)

The visual analogue scale (VAS) is a uni-dimensional self-report instrument used to measure intensity of symptoms across a continuum that ranged from zero to the most pain imaginable. The VAS was used to report pain intensity and to monitor if pain developed or changed during the experimental session. Participants were asked to rate the level of their neck pain at baseline, immediately after the intervention and at one week follow-up. The VAS is shown to be a reliable and valid instrument for measuring neck pain (Vernon & Mior, 1991), as well exhibits very high-test re-test correlations (Rosier et al., 2002). A 0 -10 cm horizontal VAS scale was utilized to measure pre- and post-intervention cervical pain intensity. The instructions provided were to “Please mark your current level of pain?” where zero was no pain and ten was the worst pain imaginable.

Neck Disability Index (NDI)

The Neck disability index (NDI) assessed the functional status of the participants (Vernon & Mior, 1991) with a self reported questionnaire that consisted of ten statements on a zero-to-five-point scale for a maximum of fifty points. Scores were converted to a score out of one hundred for statistical analysis and categorical interpretation (without, mild, moderate, severe to complete disability). Items include pain, personal care, lifting, reading, headaches,

concentration, work, driving, sleeping and recreation. Saltychev and colleagues (2024) completed a recent systematic review and meta-analysis and reported that this instrument could be considered a uni-dimensional scale measuring the construct of disability, test-retest reliability intra-class correlation coefficient were positive and significant and described as moderate (0.56) to very high (0.98), content ("expert opinion") and face validity ("patient opinion") were good, correlated well with the VAS and showed no ceiling or floor effect in the studied populations.

Cervical range of motion (CROM)

Range of movement is a common clinical evaluation for individuals with cervical pain and enables functional limitations to be assessed. The target muscle for this intervention is the upper trapezius, which is the prime mover in extension, lateral flexion, and rotation (to the contralateral side) of the cervical spine with care taken to isolate neck from trunk movement. Cervical range of movement was quantified using a CROM device. Intra-rater reliability for cervical AROM measurement of persons with and without neck pain is sufficient for the use of CROM in experimental and clinical practice (Fletcher and Bandy, 2008). A minimum detectable changes range between 3.6 degrees and 6.5 degrees for the six cervical movements has been reported (Audette et al., 2010).

A CROM device assessed each plane of active cervical motion (Performance Attainments Associates, St Paul Minnesota) using protocols previously described (Sukari et al., 2021) (Figure 2: CROM: measuring active range of motion). The goniometer utilized a magnetic yoke to measure rotational movement in the transverse plane and gravity assisted dials to measure movement in the sagittal and coronal planes. Each participant was requested to sit up straight

with their thoracic spine touching the back of the chair with arms relaxed and feet flat on the floor. The participant was observed while looking straight ahead to determine the zero degree start position. Demonstration of the movement and instruction were given for each plane of motion.

Figure 2: CROM measuring active cervical range of motion

Pain Pressure Threshold (PPT)

Pain pressure threshold (PPT) measures are used to quantify the degree of hyperalgesia within the taut band of musculature over a MTrP. The pressure algometer "preferentially stimulates deep tissue, such as muscle, tendon or joints, rather than cutaneous receptors" making this a relevant tool for studying MTrPs (Courtney et al., 2010). PPT is defined as the minimum amount of pressure needed for the sense of pressure to first change to pain (Fischer, 1987). This technique shows a high level of reliability with novice raters for symptomatic and asymptomatic individuals (Walton et al., 2011). Pain pressure readings were found to be consistent across the four measurements, as such, it was concluded that algometer readings did not demonstrate an order effect ($p < 0.05$) (Sciotti et al, 2001). PPT readings were recorded pre- and post- intervention using a digital pressure algometer (Somedic® Algometer type 2, Sollentuna, Sweden) with a 1-cm^2 rubber tipped probe. On each test-day a standardized calibration of the instrument was performed with known pressures between 0 kPa and

294.2 kPa (3 kg/cm^2). Force application was applied perpendicular to the surface of the muscle and pressure was applied at a slow constant rate of 1 kg/cm^2 per second (Fischer, 1997) to increase reliability (Jensen et al., 1986). The average of three measures was taken to decrease possible error due to variation in individual measurements (Walton et al., 2011) and a fifteen second rest was given between measures to avoid temporal summation (Chesterton et al., 2007).

During the application of pressure, the moment sensation had a qualitative shift from pressure to pain/discomfort the participant was instructed to push a button to stop the pressure stimulation. The assessor applied the pressure algometry to the MTrP and the pain threshold was recorded with a digital reader (Figure 3: PPT instrumentation). The same protocol was performed on the contralateral side. The instrument values were read by the outcome assessor and concealed from the participant and the primary investigator. This technique showed a high level of reliability with novice raters for a symptomatic neck pain population and asymptomatic individuals (Walton et al., 2011).

Figure 3: PPT instrumentation

Motor performance outcome measure

Fitts' Task Procedure

The Fitts' task was adapted to a head turning task where participants were asked to turn their head to the target as quickly and accurately as possible. The difficulty of the targeting task was determined using Fitts' task parameters of width and amplitude and five unique indices of difficulty (ID) were calculated from the four amplitudes and two target widths with the formula: $ID = Log_2(2A/W)$ (Table 1: Index of Difficulty).

Table 1: Index of Difficulty

	Target Amplitudes (A) in mm			
Target Widths (W) in mm	**87.5**	**125**	**175**	**250**
12	**3.9**	**4.4**	**4.9**	**5.4**
17	**3.4**	**3.9**	**4.4**	**4.9**

*Index of difficulty is measured in bits

For this experiment ID values were in the range of 3.9- and 5.4-bits and were within the 3 - 12 bits range of most studies (MacKenzie, 1992). Each of the eight combinations of width and amplitude were presented eight times, bilaterally in a random order for a total of one hundred twenty-eight trials. The total time to complete each Fitts' Task was approximately fifteen minutes. The participants were familiarized with the Fitts' task with verbal instructions followed by eight practice trials.

Fitts' Task Dependent Variables

The Fitts' paradigm is utilized to measure a dependent variable (MT, RT, PV, PA, ttPV, ttPA, CE, VE), while systematically varying the target by manipulating the distance and the width of the target. The width and amplitude are manipulated by the experimental model and will determine/impact the dependent variables. The dependent variables are defined below:

Movement time (MT) (seconds) describes the duration of time to complete a discrete, predefined motor task. Recording MT begins at movement initiation and ends at the completion of the task.

Reaction time (RT) (seconds) is the duration of time from the onset of the prompt on the screen to movement initiation. RT has a built in minimal cut off in the model of 100 milliseconds.

Peak Velocity (PV) (meters/second) is the maximal velocity observed during the movement phase.

Peak Acceleration (PA) (meters/second^2) is the maximal acceleration observed during the movement phase.

Time to peak velocity (ttPV) (milliseconds) is the time from movement onset to peak velocity.

Time to peak acceleration (ttPA) (milliseconds) is the time from movement onset to peak acceleration.

Constant Error (CE) (degrees) measures the average distance a participant's final position deviates from the center of the target. Directional bias is observed as overshooting or undershooting of the target. Perfect accuracy takes the value of zero, positive values represent an overshoot, and negative values represent an undershoot of the target center.

Variable Error (VE) (degrees): measures the variability in each participant's performance represented by the standard deviation from the final head position. VE is a measure of movement consistency of the final position of rotation and error may be a consequence of disturbed position sense acuity (Sjolander et al., 2008).

Fitt's Task Instrumentation

The Fitts' head turning task and equipment used to quantify cervical motor performance were adapted from previous publications (Descarreaux et al., 2010; Passmore et al., 2007, Passmore et al., 2010). Each participant sat 60 cm from a 34" curved computer monitor (3440 x 1720-pixel resolution), on which a head mouse with an optical transceiver was mounted at eye level and centered on top of the computer screen (Headmouse Nano, Origin Instruments Corporation, Grand Prairie, Texas) (Figure 4: Instrumentation set-up). The participant wore clear protective glasses with a 5 mm reflective marker on the nose bridge to enable the head mouse to capture and record head rotation. Computer-based timing software (E-prime, Version 2.0, Psychology software tools Inc, USA) was installed on the computer and was connected to the head mouse. The software was calibrated for the screen size to maintain amplitude and target accuracy. The task was initiated when the participants clicked on a "+" sign in the center of the screen with a hand-mouse. The "+" sign stayed on the screen for a random fore-period (1100 msec to 2100 msec). The fore-period was utilized to reduce anticipation and encourage participants to move on the true go signal. Once the fore-period passed the "+" sign disappeared, and a blue square target appeared on the screen. The participants were instructed to turn their head as quickly and accurately as possible to the target with the head-mouse. Five

percent of peak velocity was utilized to define the start and end of MT, when the participants head velocity exceeded this threshold movement began and when it fell below for 200 msec or 20 samples movement stopped (Sjolander et al., 2008).

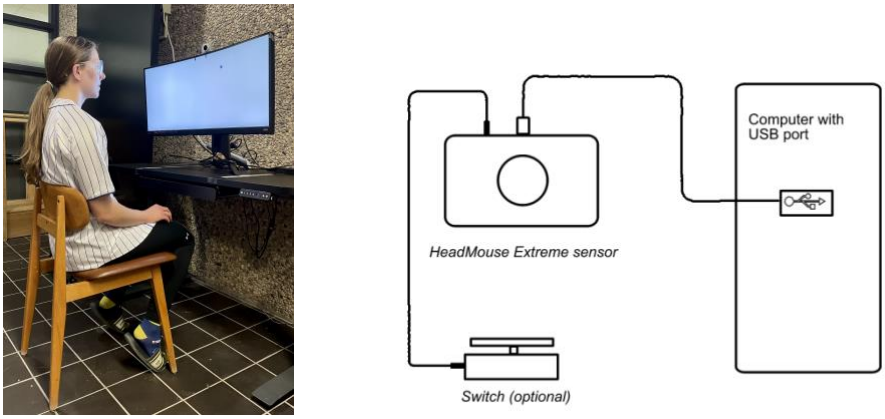


Figure 4: Fitts' task Instrumentation set up

Data Processing and Analysis

The Fitts' task software, E-prime (E-prime, version 2.0, Psychology Software Tools Inc, USA) produced raw pixel data, which was exported to a Microsoft Excel template (version 16.80, 2023). Here, the data was organized, coded for amplitude, width, and side. To calibrate from pixels to the universal measure of degrees, the Pythagorean theorem was utilized based on the pixel location for each amplitude and the distance from the monitor. The data was filtered twice (forward and reverse) with a low pass Butterworth filter with a sampling frequency of 100 Hz (10 msec sample interval) and a cut off frequency of 5Hz. Five-point numerical differentiation was used to derive velocity from the movement time and a second round of differentiation calculated acceleration from velocity. Displacement, velocity, and acceleration were plotted graphically.

Each individual trial was reviewed graphically prior to data analysis to ensure the trial was valid (free from equipment artifacts and displayed a representative response in keeping with the Fitts' task). Trials were corrected in cases where at the onset of movement the participant's position was adjusted slightly and stopped prior to making a clear movement to the target. These early velocity values were deleted to enable the template to capture the desired movement of the head turning task. Only erroneous data points that did not follow a clear movement to the target were deleted. Data points caused by variations in reaction times and/or movement times due to human behavior remain in the data set and were managed by extracting the median for our data. As a measure of central tendency, the median is less effected by extreme values than the mean (Ripley, 2004). The performance of a median data set was compared to a mean data set with outliers removed (identified through box plots and deleted) in a repeated measures ANOVA and the results found no difference between the data sets.

Follow up Questions

One week after the lab session, participants responded to an emailed questionnaire consisting of a VAS and three questions about the blinding procedure using a seven-point Likert scale. The first question quantified the sensation (discomfort/pain) during the intervention, the second quantified the experience of muscle spasm or LTR and the third question quantified opinion of the participants on whether they received the genuine treatment. A final qualitative question was asked about the duration of discomfort following the intervention.

Statistical platform and statistical test assumptions

Statistical analysis was conducted using the R based statistics platform Jamovi (The jamovi project [2023]. *jamovi*. [Version 2.4] [Computer Software]. Retrieved from https://www.jamovi.org). The significance level for all statistical tests was set at $p < 0.05$. Statistical assumptions were assessed for both t-tests (Shaprio-Wilk test for normality, Q-Q plots, and Levine's test for homogeneity) and ANOVA (Shapiro-Wilk for normality, Q-Q plots, Mauchly's test for sphericity and Levine's test for homogeneity of variance). Where indicated, a Greenhouse-Geisser correction and/or non-parametric tests were utilized.

Statistical tests and experimental models

The demographic data underwent independent sample t-tests for age, sex, weight, and BMI. A repeated measures ANOVA was utilized for VAS with a 2 (group) x 3 (time) model, for NDI with a 2 (group) x 2 (time) model, and for pain pressure threshold with a 2 (group) x 2 (time) x 2 (side) design. Cervical range of movement compared each plane of movement independently using a repeated measures ANOVA with a 2 (group) x 2 (time) x 2 (direction) design. The DN LTR was assesses for significant difference between paired observations (right and left) in the same individual in the treatment group was assessed using a paired t-test. The statistical analysis of the follow up questions utilized a nonparametric one-way ANOVA. The model for the Fitts' task dependent variables was a 2 (group: DN/sham) x 2 (time: pre/post) x 2 (side: left/right) x 2 (width: 12/17) x 4 (amplitude 8.3, 11.8, 16.3, 22.6) repeated measure ANOVA. When no significant effect or interactions with side were found, the variable of side was collapsed effectively creating a 2 x 2 x 2 x 4 repeated measures ANOVA. For each

dependent variable analysis, the treatment group was a between subjects' factor and the other independent variables were within subject factors. The 'main effect' in terms of time, group, width, amplitude, and the interactions were reported. Post hoc Tukey's was employed for pairwise analysis of the interactions.

Results

Descriptive Statistics

The participant baseline characteristics for this study are found in Table 2. There were no significant differences between the groups for age (p = 0.884), weight (p = 0.283), height (p = 0.983), BMI (p = 0.217) and pre-intervention VAS (p = 0.511) and NDI (p = 0.937).

Table 2: Participant Demographics Baseline Characteristics

	DN	Sham	p-value
N	18 (50%)	18 (50%)	
Sex (M:F)	9:9	7:11	
Age (years)	34.8 (5.90)	35.1 (5.46)	0.884
Weight (kg)	86.3 (19.3)	77.6 (13.6)	0.283
Height (cm)	173 (10.9)	173 (10.5)	0.983
BMI	28 (5.79)	25.9 (3.67)	0.217
VAS pre	2.46 (2.19)	2.88 (1.57)	0.992
NDI pre	14.8 (8.49)	14.6 (8.23)	0.992

Data comparison (mean, standard deviation or %) between treatment and sham groups
VAS: Visual analogue scale (/10 cm line)
NDI: Neck Disability Index questionnaire (/100).

Intervention of dry needling and the local twitch response

The DN needling intervention consistently produced LTRs in all the participants in the treatment group. The median number of LTRs observed was four on the left and five on the right. The minimum number of LTRs reported was one on the left and two on the right. A

paired sample t-test found no significant difference between sides (p = 0.100). The sham group was not confounded by displaying any twitch responses.

Clinical Outcome Measures

Pain and disability measures

An overview of VAS and NDI experimental results are found below (Table 3: VAS & NDI results).

Table 3: VAS and NDI results

	Treatment	**Sham**	***p* value**
VAS (pre)	2.46 (2.19)	2.88 (1.57)	0.992
VAS (post)	2.74 (1.51)	1.86 (1.68)	0.479
VAS (follow-up)	1.65 (1.93)	1.41 (1.58)	0.999
NDI (pre)	14.8 (8.49)	14.6 (8.23)	0.992
NDI (follow up)	11.1 (8.47)	10 (9.22)	0.983

Mean (SD), VAS: Visual analogue scale (/10 cm line)
NDI: Neck Disability Index questionnaire (/100).

Analysis of the VAS scores revealed the main effect of group was not significant ($F_{1,32}$ = 0.282, p = 0.599). A main effect of time was present ($F_{2,64}$ = 8.83, p < 0.001) with a Group * Time interaction approaching significance ($F_{2,64}$ = 3.11, p = 0.051) (Figure 5: VAS: Time * Group interaction). Post hoc comparisons found no significant differences between the treatment groups at any time point, however with respect to time, the sham group reached significance from baseline to follow-up ($p_{Tukey's}$ < 0.008).

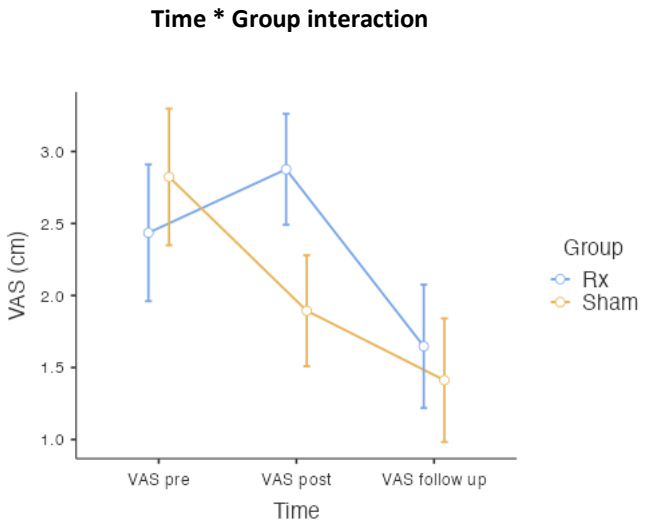


Figure 5: VAS: Time * Group Interaction

A significant decline in NDI scores was observed with the main effect of time ($F_{1,32} = 14.206$, $p < 0.001$). There was no significant effect of group ($F_{1,32} = 0.124$, $p = 0.727$), nor any significant Group * Time interaction ($F_{1,32} = 0.017$, $p = 0.896$) (Figure 6: NDI: Time * Group interaction).

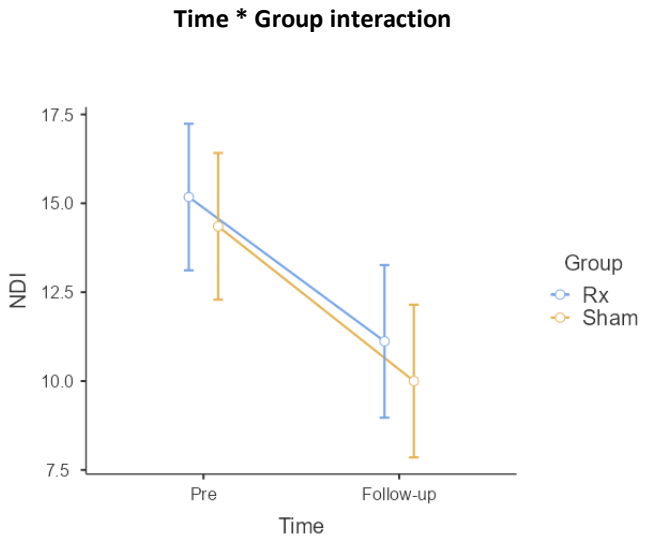


Figure 6: NDI: Time * Group Interaction

Pressure Algometry

Pain pressure thresholds increased with respect to time ($F_{1,33} = 44.069$, $p < 0.001$). Results show no main effect of group ($F_{1,33} = 0.005$, $p = 0.942$) indicating both the DN and sham groups had similar increases in tolerance to pressure algometry (Figure 7: Pressure Algometry: Time * Group interaction). The main effect of side ($F_{1,33} = 3.554$, $p = 0.068$) was not significant and no group interactions were found. The tolerance to pressure improved from pre-intervention (mean 402 KPa [SE 26.3, 95% CI 349-456]) to post-intervention (mean 468 KPa [SE 25.3, 95% CI 417- 520]).

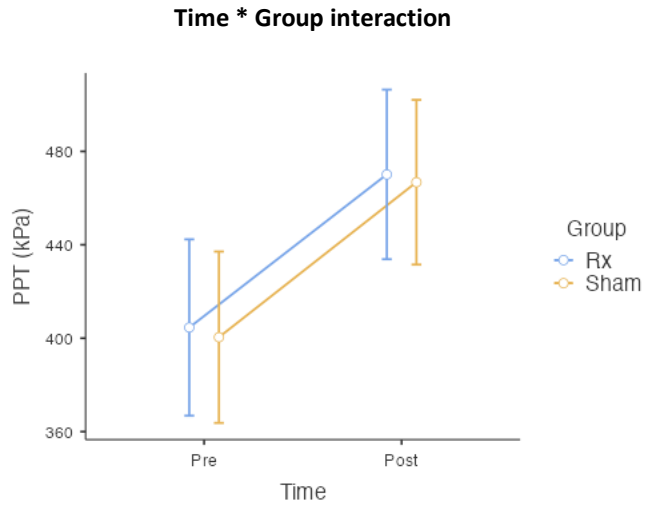


Figure 7: Pressure Algometry: Time * Group Interaction

Cervical range of motion (CROM)

There were no significant main effects in any plane of CROM between groups, over time, or in movement direction (except for cervical flexion). The CROM data from this experiment is consistent with aged matched normative data (Table 4: CROM) (Youdas et al., 1992).

Table 4: CROM (degrees): Mean Values and Normative Data

	DN		Sham		Normative
	Pre	**Post**	**Pre**	**Post**	**data**
Flexion	47.8 (12.2)	52.3 (12.9)	57.2 (13.1)	58.1(12.6)	47.3 (9.5)
Extension	61.4 (15.9)	60.8 (14.4)	63.3 (9.49)	65.6 (7.79)	73.1 (13.3)
Right rotation	62.4 (10.3)	59.5 (8.36)	65.1 (7.26)	65.0 (7.59)	69.4 (6.6)
Left rotation	61.7 (10.3)	64.3 (10.4)	67.6 (9.03)	70.0 (10.2)	65.8 (8.6)
Right lateral flexion	40.4 (11.1)	40.8 (11.5)	44.8 (8.91)	46.7 (10.3)	44.7 (8.5)
Left lateral flexion	41.0 (12.5)	41.7 (7.01)	44.9 (12.4)	46.7 (9.40)	42.4 (9.1)

Values = Mean (SD), Normative data: 30–39-year-old subjects, Mean age (SD) for DN: 34.8 (5.90) and sham 35.1 (5.46).

Flexion/Extension

For flexion and extension, the main effect of group ($F_{1,34} = 2.44$, $p = 0.128$) and time ($F_{1,34} = 3.49$, $p = 0.070$) were not significant (Figure 8: CROM: Flexion/Extension: A: Time * Group Interaction). The main effect of direction of movement was significant ($F_{1,34} = 20.839$, $p < 0.001$) confirming a greater amount of cervical extension compared to flexion with a significant 3-way interaction between Time * Direction * Group ($p_{Tukey's} = 0.026$). The only meaningful pairwise comparison was a significant difference between flexion and extension at baseline for the

treatment group ($p_{Tukey's} = 0.003$) and the same comparison was not significant for the sham group (Figure 8: CROM: Flexion/Extension B: Time * Direction * Group Interaction). While modest, these data suggest that cervical flexion was reduced at baseline in the Rx group and improved slightly after DN.

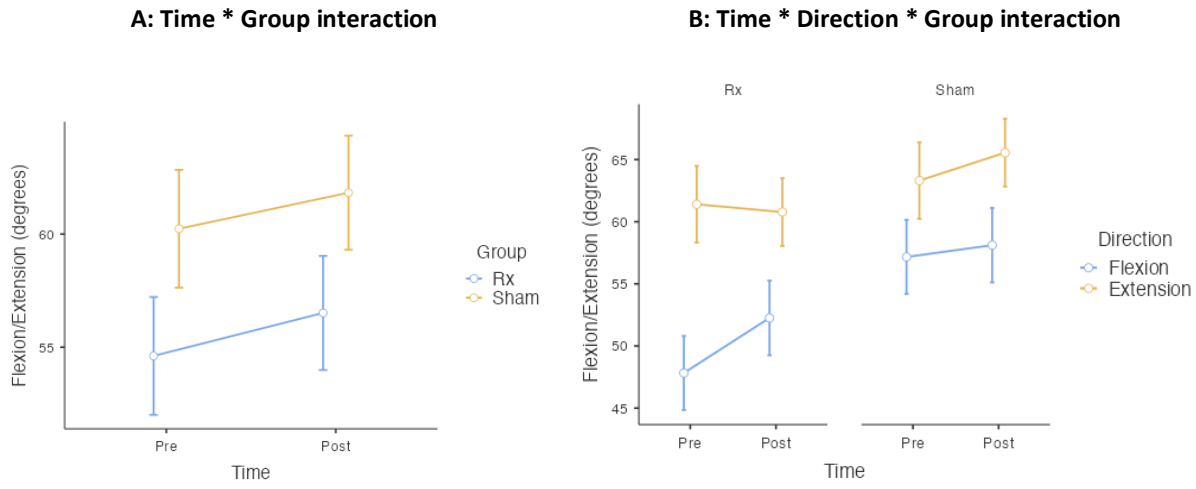


Figure 8: CROM: Flexion/Extension

Lateral Flexion

There were no statistically significant differences in lateral flexion between the two groups ($F_{1,34} = 2.18$, $p = 0.149$), over time ($F_{1,34} = 2.337$, $p = 0.136$), or between different sides ($F_{1,34} = 0.166$, $p = 0.686$) and no interactions were significant (Figure 9: CROM: Lateral Flexion).

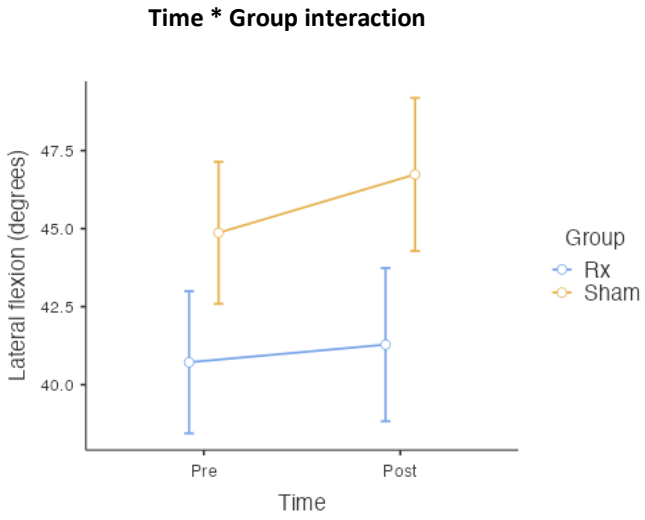


Figure 9: CROM: Lateral Flexion

Rotation

For rotation, there were no significant main effects for group ($F_{1,34} = 4.06$, $p = 0.052$), time ($F_{1,34} = 0.544$, $p = 0.466$) or side ($F_{1,34} = 3.94$, $p = 0.055$) with no significant interactions (Figure 10: CROM: Rotation)

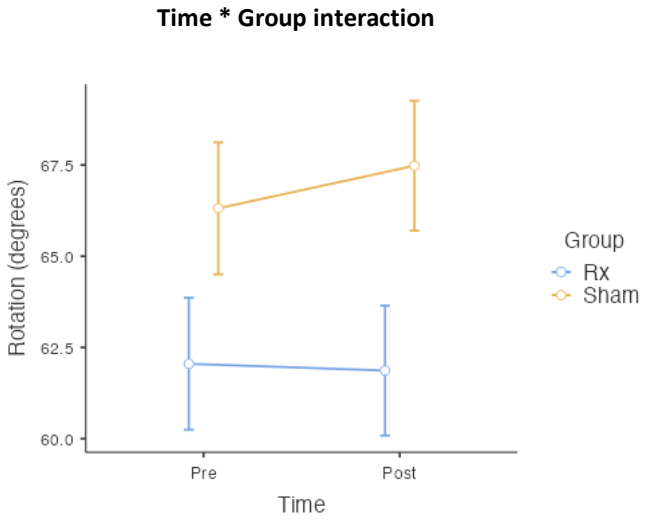


Figure 10: CROM: Rotation

Fitts' Task Dependent Variable Results

Primary Outcome Movement Time (MT)

MT: Between group analysis

Results for MT revealed a significant main effect of time ($F_{1,34} = 23.352$, $p < 0.001$) and group ($F_{1,34} = 7.02$, $p = 0.012$) such that both groups showed a decrease in MT from pre- to post-treatment. The Time * Group interaction was not significant ($F_{1,34} = 0.012$, $p = 0.913$) (Figure 11: MT: Between Group Analysis). The mean difference in MT between the DN and sham groups was 123 msec and between baseline and post intervention was 52 msec.

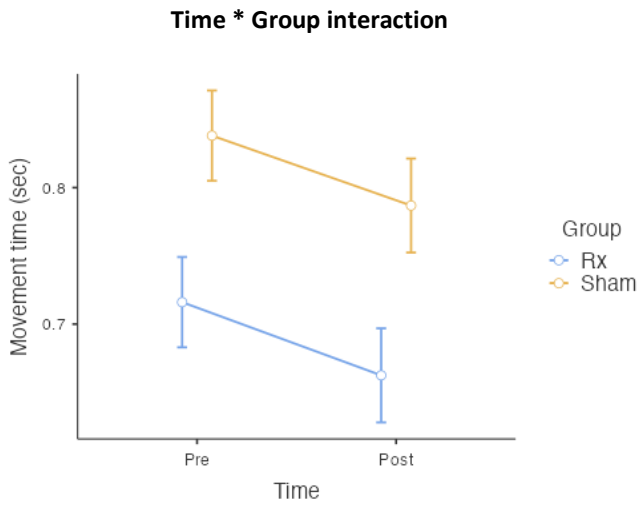


Figure 11: MT: Between Group Analysis

MT: Within group analysis

Varying the target width ($F_{1,34} = 5.952$, $p = 0.020$) and amplitude ($F_{3,102} = 15.911$, $p < 0.001$) had a statistically significant impact on MT with no significant Width * Amplitude interactions. (Figure 12: MT: Within Group Analysis). Post-hoc comparisons for amplitude show

that MT for the 22.6 target was greater than all the others ($p_{Tukey's} = < 0.001$) which were not different from each other. The significant main effects of target width and amplitude show a trend towards longer MTs with smaller or more distant targets (Figure 12: MT: Within Group Analysis).

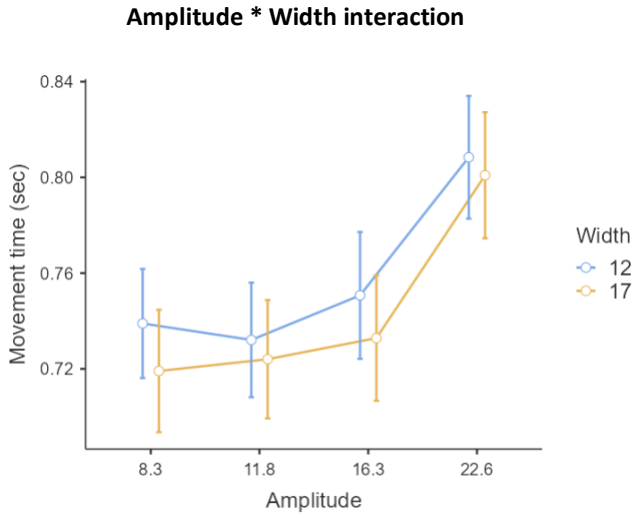


Figure 12: MT: Within Group Analysis

Peak Velocity (PV)

PV: Between group analysis

The main effect of group was significant for PV ($F_{1,34} = 5.25$, $p = 0.028$) with the DN group showing higher PV compared to the sham. The main effect of time was not significant ($F_{1,34} = 2.410$, $p = 0.130$). The Group * Time interaction was approaching significance ($F_{1,34} = 4.106$, $p = 0.051$); post hoc analysis did not reveal any significant pairwise comparisons although PV tended to be higher in the treatment group after DN (p = 0.73) (Figure 13: PV: Between Group Analysis).

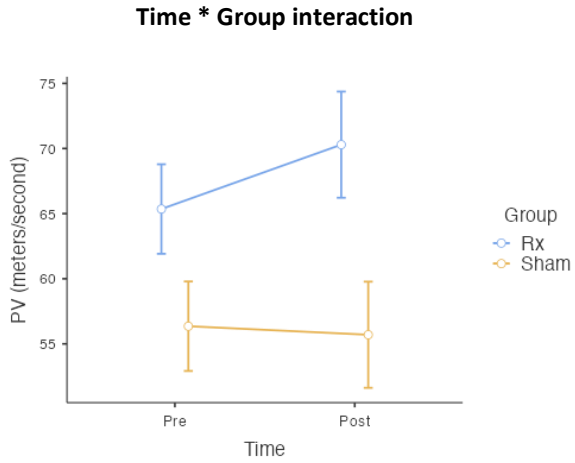


Figure 13: PV: Between Group Analysis

PV: Within group analysis

For PV, the analysis revealed no significant main effects or interactions for target width ($F_{1,34} = 3.233$, $p = 0.081$). A significant main effect of amplitude was observed ($F_{3,102} = 490.536$, $p = < 0.001$). Despite a significant Amplitude * Group interaction ($F_{3,102} = 3.460$, $p = 0.019$) and Time * Amplitude ($F_{3,102} = 3.422$, $p = 0.020$) neither of the post hoc comparisons yielded any results beyond the main effect of amplitude (Figure 14: PV: Within Group Analysis).

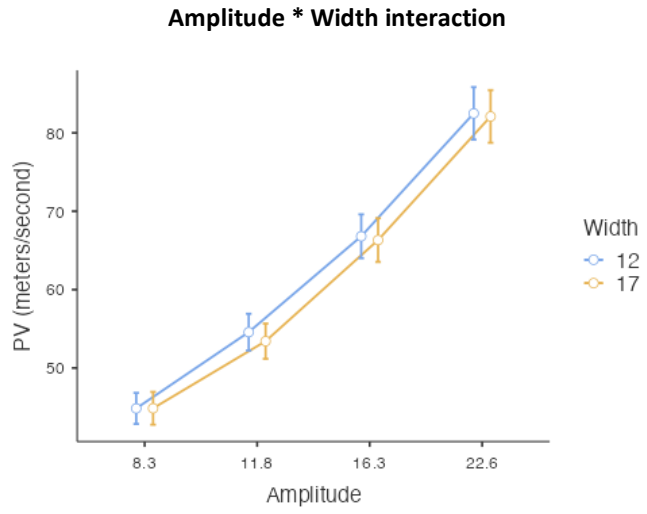


Figure 14: PV: Within Group Analysis

Peak Acceleration

PA: Between group analysis

A significant main effect of group was seen for PA ($F_{1,34} = 5.40$, $p = 0.026$) with no significant effect of time ($F_{1,34} = 2.901$, $p = 0.098$) or Group * Time interactions ($F_{1,34} = 3.186$, $p = 0.083$). A similar weak trend to increased PA was seen in the treatment group after DN (p= 0.084) (Figure 15: PA: Between Group Analysis).

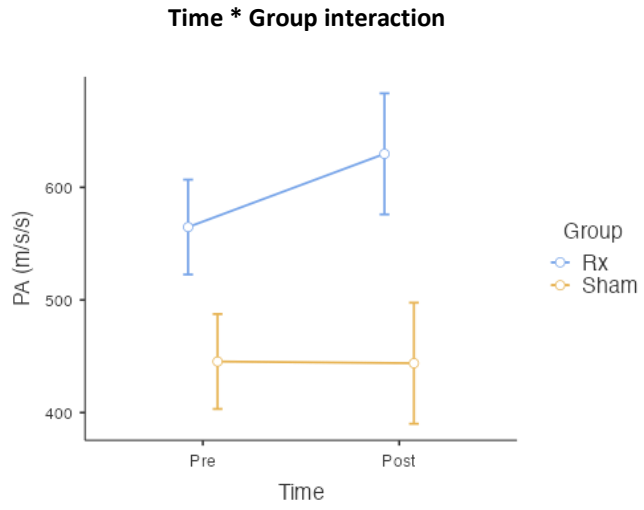


Figure 15: PA: Between Group Analysis

PA: Within group analysis

The main effect of width was not significant ($F_{1,34} = 0.388$, $p = 0.538$). The main effect of amplitude was significant ($F_{3,102} = 173.307$, $p < 0.001$) (Figure 16: PA: Amplitude * Width Interaction). A significant interaction was found for Amplitude * Group ($F_{3,102} = 4.018$, $p = 0.010$); however pairwise comparisons revealed nothing more than the main effects of amplitude.

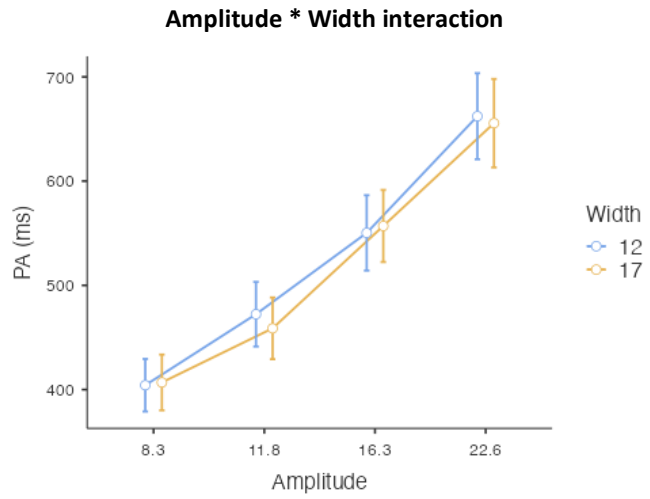


Figure 16: PA: Within Group Analysis

Time to Peak Velocity (ttPV)

ttPV: Between group analysis

ttPV was statistically significant with respect to the main effect of time ($F_{1,34} = 7.806$, $p = 0.008$) with no significant effect of group ($F_{1,34} = 0.719$, $p = 0.402$) or interactions ($F_{1,34} = 5.59$, $p = 0.981$) (Figure 17: ttPV: Between Group Analysis).

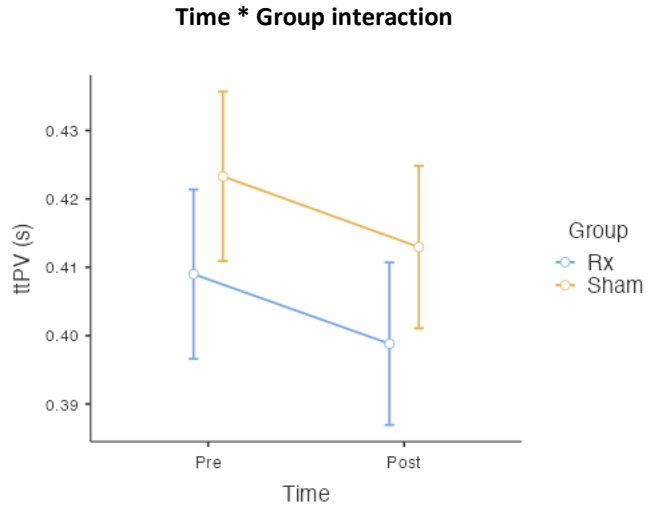


Figure 17: ttPV: Between Group Analysis

ttPV: Within group analysis

Significant main effects were found for both width ($F_{1,34} = 4.207$, $p = 0.048$) and amplitude ($F_{3,102} = 37.241$, $p < 0.001$) with significant Width * Amplitude interactions ($F_{3,102} = 2.977$, p = 0.035). The interaction appears to be the result of spurious data coinciding with at the third amplitude (16.3) and the smaller target width (12) causing a deviation from the pattern observed by the other widths and amplitudes. This interaction did not yield any more information that the main effects (Figure 18: ttPV: Within Group Analysis).

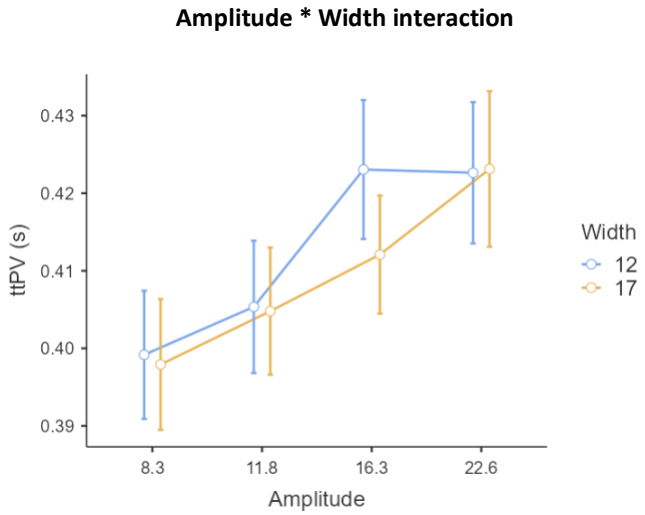


Figure 18: ttPV: Within Group Analysis

Time to Peak Acceleration (ttPA)

ttPA: Between group analysis

The main effect of group for ttPA was not significant ($F_{1,34} = 0.068$, $p = 0.796$). The main effect of time ($F_{1,34} = 6.058$, $p = 0.019$) was significant with no Time * Group interactions ($F_{1,34} = 0.032$, $p = 0.859$) (Figure 19: ttPA: Between Group Analysis).

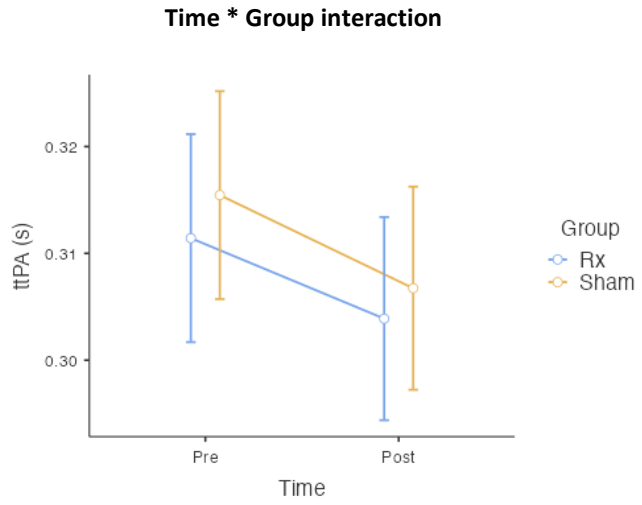


Figure 19: ttPA: Between Group Analysis

ttPA: Within group analysis

Both target parameters influenced ttPA with significant main effects of width ($F_{1,34}$ = 11.558, p = 0.002) and amplitude ($F_{3,102}$ = 7.208, p < 0.001). There were no significant group interactions (Figure 20: ttPA: Within Group Analysis).

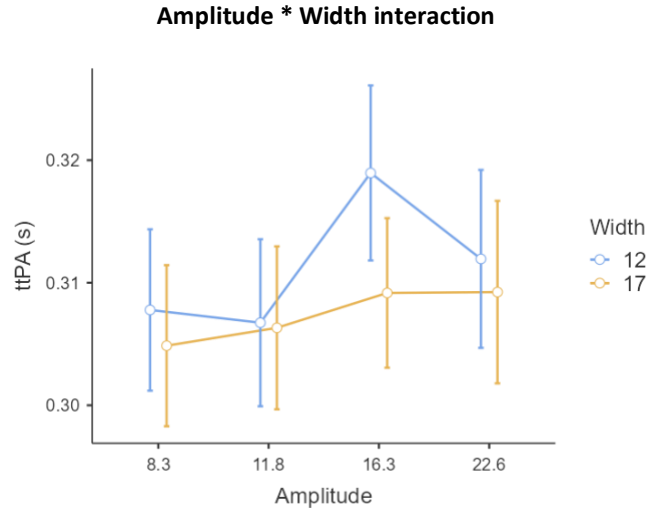


Figure 20: ttPA: Within Group Analysis

Constant error (CE)

CE: Between group analysis

Group membership ($F_{1,34} = 5.07$, $p = 0.031$) and time ($F_{1,34} = 13.537$, $p < 0.001$) significantly influence CE in the study, with no Group * Time interactions (Figure 21: CE: Between Group Analysis). Both groups could be characterized as undershooting the targets which was reduced after both interventions.

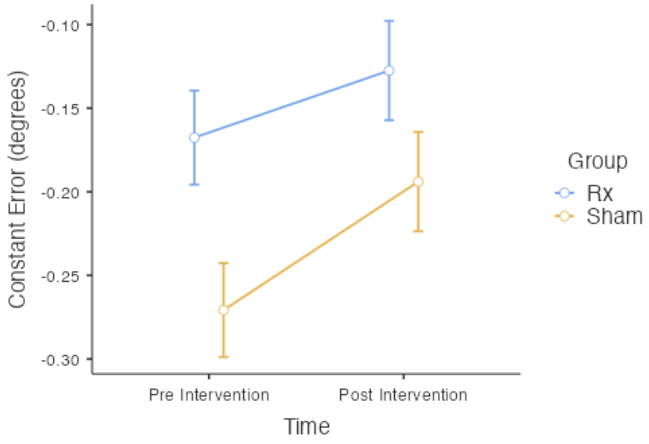


Figure 21: CE: Between Group Analysis

CE: Within group analysis

For CE there were no significant main effects for width ($F_{1,34} = 2.874$, $p = 0.099$). The main effects for amplitude ($F_{3,102} = 193.461$, $p < 0.001$) reached significance with a pattern of undershooting at the first three target amplitudes and overshooting at the fourth target amplitude. Significant interactions were found for Width * Amplitude ($F_{3,102} = 7.878$, $p < 0.001$) and Time * Amplitude ($F_{3,102} = 2.726$, $p = 0.048$) (Figure 22 A and B). The Width * Amplitude interaction post hoc comparisons confirmed a significant difference only at the highest amplitude (22.6) ($p_{Tukey's} < 0.001$) (Figure 22 A: CE: Amplitude * Width interaction). The

Amplitude * Width interaction captures the tendency to overshoot at the highest amplitude and a significant difference between the target widths at the highest amplitude ($p_{Tukey's} <$ 0.018). The Amplitude* Time interaction captures a significant difference from pre- to post-intervention only at the lowest amplitude ($p_{Tukey's} = 0.012$) (Figure 22 B: CE: Amplitude * Time Interaction).

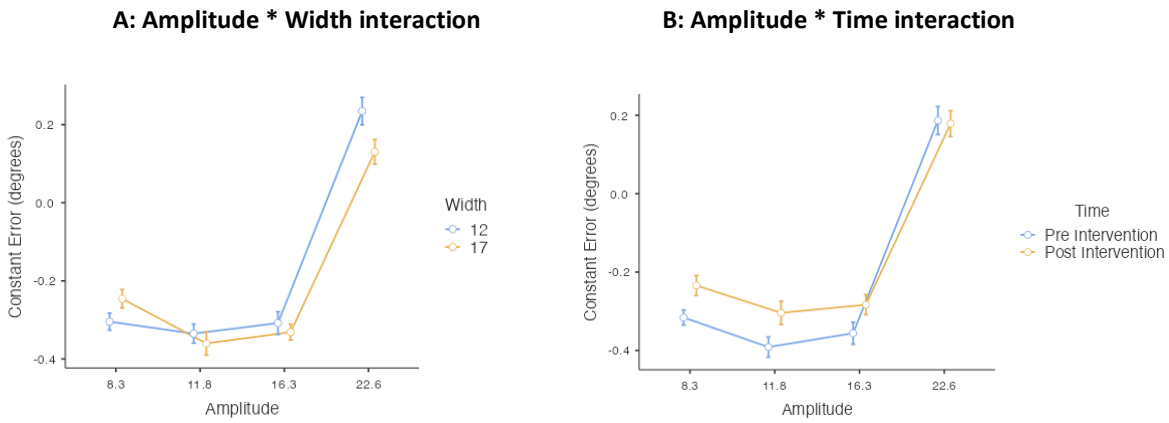


Figure 22: CE: Within Group Analysis

Variable Error (VE)

VE: Between group analysis

VE is not significantly different between the two groups ($F_{1,34} = 3.35$, $p = 0.076$), however VE did improve over the two time points ($F_{1,34} = 11.314$, $p = 0.002$) indicating participants were more consistent in their head movements after both interventions (Figure 23: VE: Between Group Analysis).

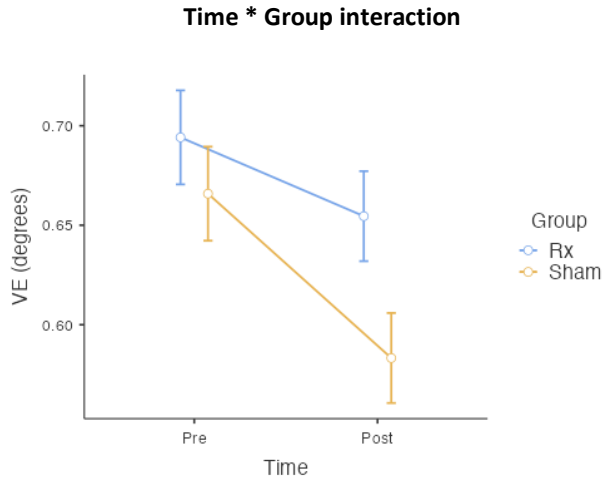


Figure 23: VE: Between Group Analysis

VE: Within group analysis

For VE, there is a significant main effect of both width ($F_{1,34}$ = 5.139, p = 0.030) and amplitude ($F_{3,102}$ = 34.878, p < 0.001). The VE increases with the larger target and with higher amplitudes depicted in Figure 24 below.

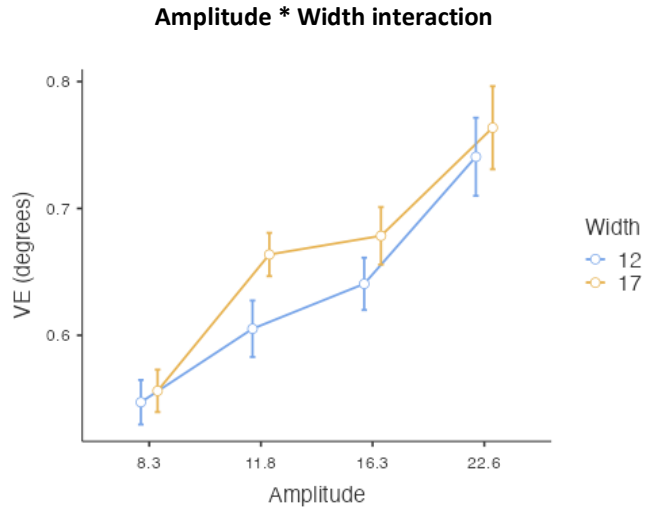


Figure 24: VE: Within Group Analysis

A significant interaction is found with Amplitude * Group ($F_{3,102} = 4.613$, $p = 0.005$), but only confirmed the main effects. No group comparisons were significant, however amplitude reached significance with comparisons of the closest (8.3) to the furthest (22.6) amplitudes in both groups, but only the DN group reached significance comparing the middle two targets (11.8 and 16.3) to the highest amplitude (Figure 25: VE: Amplitude * Group Interaction).

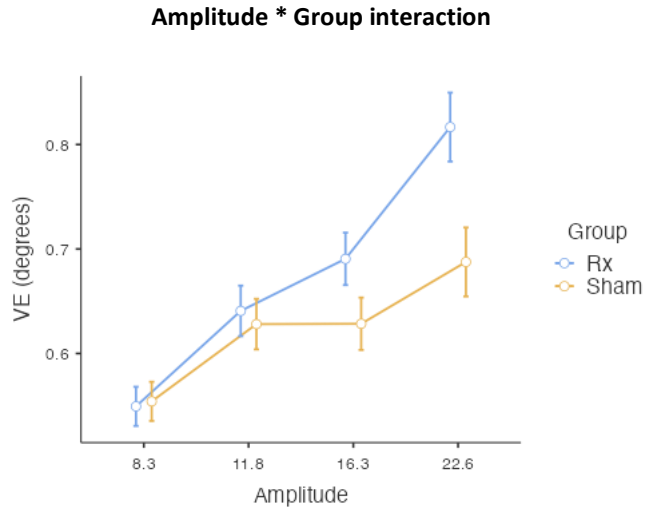


Figure 25: VE: Within Group Analysis

VE also has a significant interaction of Time * Width ($F_{1,34} = 4.804$, $p = 0.035$) with two significant pairwise comparisons: the larger target from baseline to post intervention (pre/17 and post/17, $p_{Tukey's} = 0.004$) and the two targets at baseline (pre/12 and pre/17, $p_{Tukey's} = 0.017$) (Figure 26: VE: Within Group Analysis).

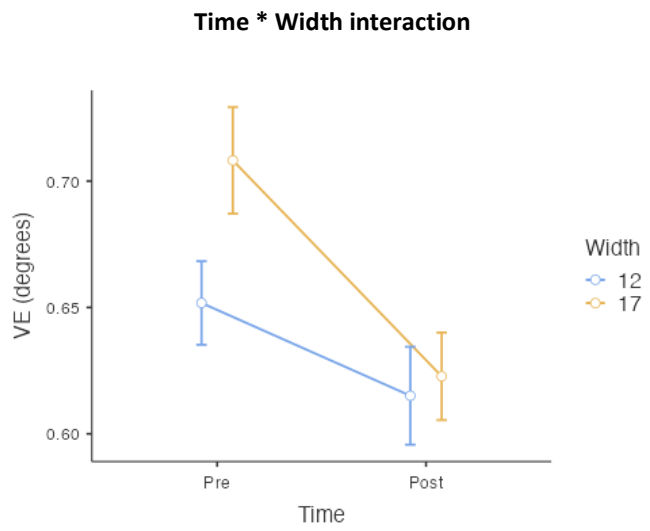


Figure 26: VE: Within Group Analysis

Reaction time (RT)

RT: Between group analysis

RT's main effect of group was not significant ($F_{1,34} = 0.428$, $p = 0.517$), but a significant reduction in RT from pre-post intervention was found ($F_{1,34} = 9.84$, $p = 0.004$) without significant Time * Group interactions ($F_{1,34} = 0.230$, $p = 0.634$) (Figure27: RT: Between Group Analysis). Regardless of the statistical outcomes, the absolute differences for these comparisons (~0.008 seconds) are less than the head mouse sample interval of 0.010 seconds and, therefore, should not be interpreted as meaningful.

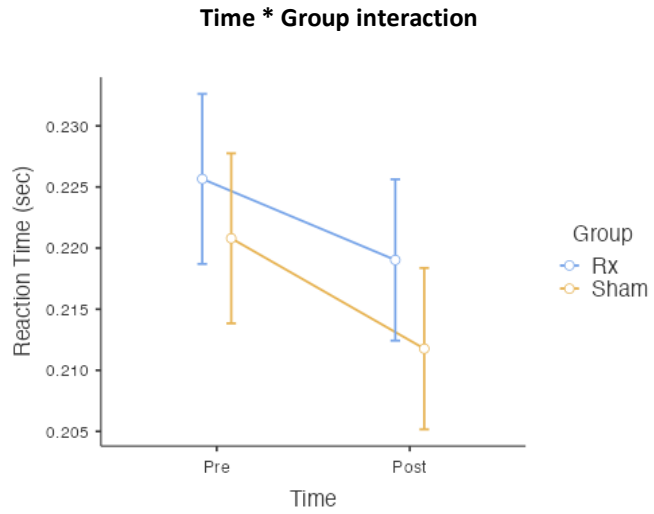


Figure 27: RT: Between Group Analysis

RT: Within group analysis

The main effect of target width was significant ($F_{1,34} = 5.356$, $p = 0.027$) with the larger target resulting in faster RTs. The main effect of amplitude was significant with more distant targets resulting in faster RT ($F_{3,102} = 9.322$, $p < 0.001$). The Width * Amplitude interaction yielded a significant result ($F_{3,102} = 3.655$, $p = 0.015$), but was likely due to anomalies in the data generated from the smaller width (12) at the third amplitude (16.3). Post hoc analysis revealed three significant pairwise comparisons (12 x 11.8/12 x 16.3, $p_{Tukey's} = 0.016$; 12 x 16.3/12 x 22.6, $p_{Tukey's} < 0.001$; 12 x 16.3/17 x 16.3, $p_{Tukey's} = 0.012$) (Figure 28: RT: Within Group Analysis). Again, owing to hardware limitations, these differences cannot be considered meaningful at this point.

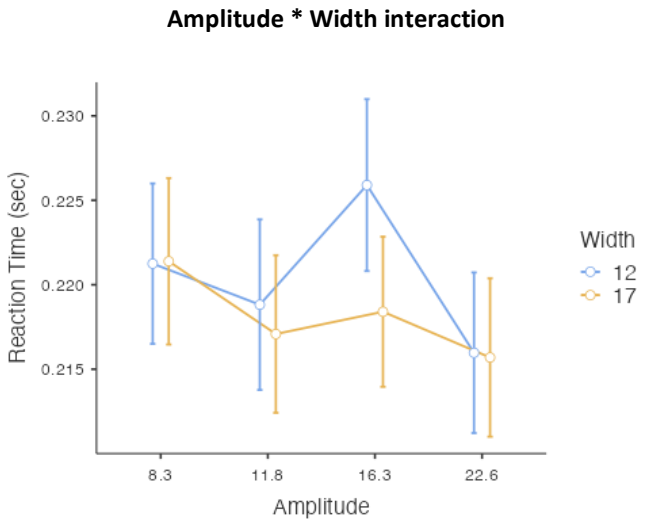
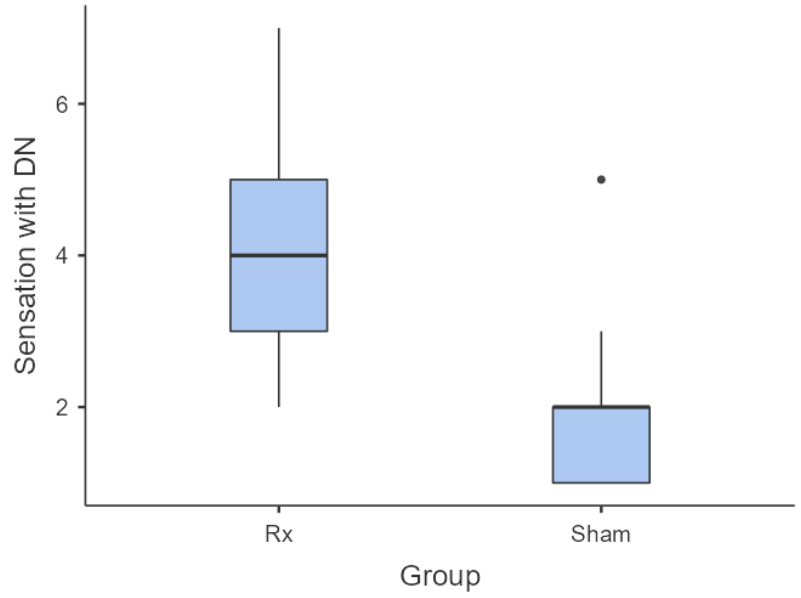


Figure 28: RT: Within Group Analysis

Assessment of the blind

Sensations during the needling interventions

A significant difference between the DN and sham groups ($p < 0.001$) was found when describing the sensation of the discomfort during the intervention. The DN group reported higher median pain scores of 4/7 compared to the sham group with 2/7 (Figure 29: Box and Whisker Plot: Sensation associated with DN).



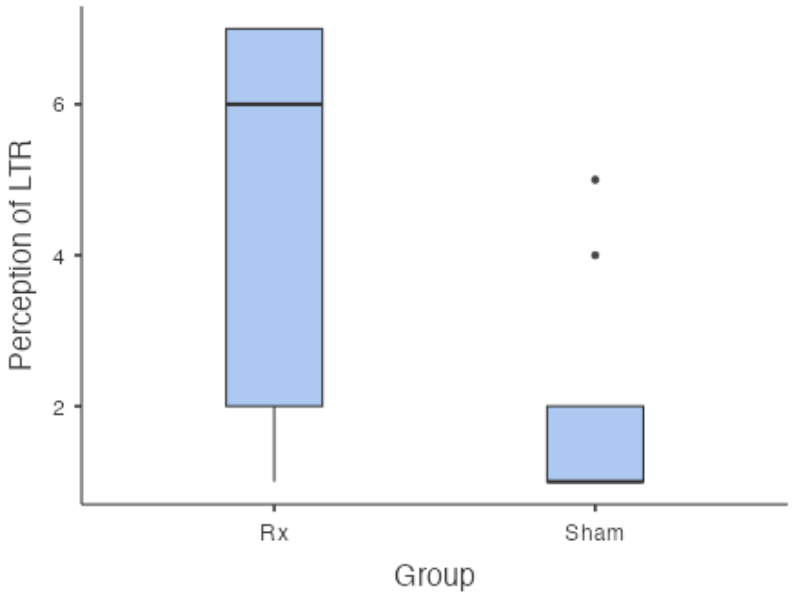
*Centre line: median. Boundaries of the box: the interquartile range. Whisker: represents the minimum and maximum values that do not exceed 1.5 * IQR

Figure 29: Box and Whisker Plot: Sensation associated with DN

Local twitch response (LTR)

The quantification of the spasm or local twitch response median values were reported. A one-way ANOVA revealed that the difference between the groups were statistically significant ($p < 0.001$). The two outliers could be attributed to instances where the needle

inadvertently contacted a superficial cutaneous nerve, causing a "stinging sensation" or pain response, which participants might have interpreted as a twitch or spasm (Figure 30: Box and Whisker Plot: LTR participant perception).

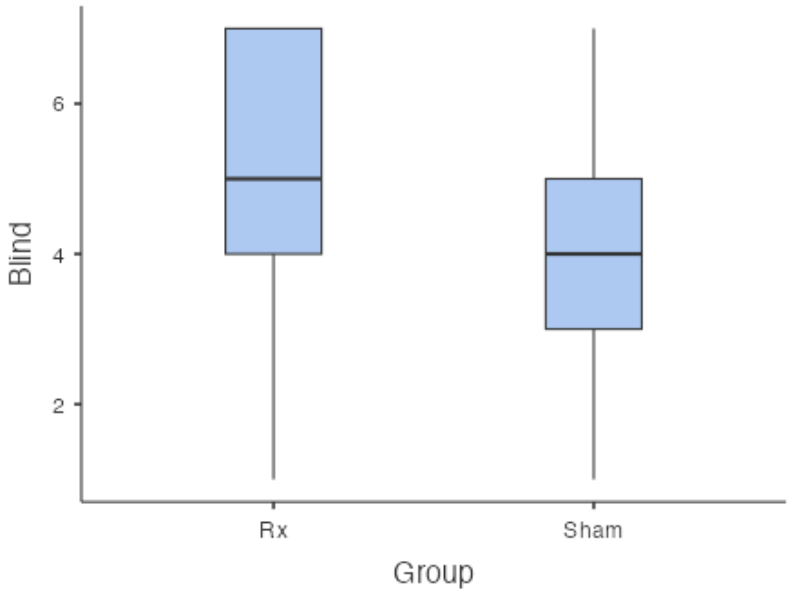


*Centre line: median. Boundaries of the box: the interquartile range. Whisker: represents the minimum and maximum values that do not exceed 1.5 * IQR

Figure 30: Box and Whisker Plot: LTR participant perception

Blinding assessment

The blinding procedure appeared effective, as participants were uncertain of their group assignment. Median scores were reported as 5/7 for the treatment group and 4/7 for the sham group. The treatment group trended toward the higher end of the scale, while the sham group trended toward the middle or lower end. A one-way nonparametric ANOVA (Kruskal-Wallis) analysis confirmed that there were no significant differences between the two groups (p = 0.066). This suggests that the perceived effectiveness of the intervention or confidence in group assignment did not significantly differ between the treatment and sham group (Figure 31: Box and Whisker Plot: Blinding success).

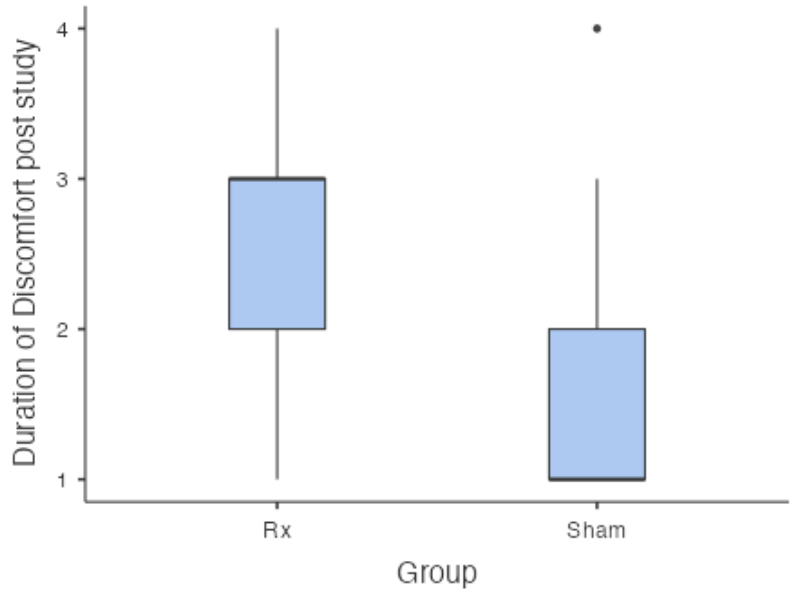


*Centre line: median. Boundaries of the box: the interquartile range. Whisker: represents the minimum and maximum values that do not exceed 1.5 * IQR

Figure 31: Box and Whisker Plot: Blinding success

Duration of discomfort following the lab session

A qualitative question investigating the participants perceived discomfort after the intervention scored had four possible answers including: no discomfort, a few hours of discomfort, discomfort until the next day, and discomfort that lasted more than one day. The median values of discomfort reported were 3 for the DN treatment group and 1 for the sham procedure (Figure: Box and Whisker Plot: Duration of perceived discomfort post study).



*Centre line: median. Boundaries of the box: the interquartile range. Whisker: represents the minimum and maximum values that do not exceed 1.5 * IQR

Figure 32: Box and Whisker Plot: Duration of perceived discomfort post study

Discussion

The objective of this study was to demonstrate treatment efficacy of a DN intervention compared to a sham procedure in participants with recurrent neck pain with latent MTrPs. The typical clinical outcome measures of pain, range of motion, disability questionnaires and pressure algometry were employed to assess DN's efficacy. These valid and reliable clinical outcome measures allow inferences to be made into functional capabilities, however these measures also expose the lack of a direct, precise empirical measure of motor function for the cervical spine in the current research. To fill this gap, a Fitts' cervical aiming task is utilized to provide an objective quantitative measure of cervical motor performance for the purpose of examining the efficacy of a DN intervention.

Clinical Outcomes

Active ranges of motion of the cervical spine were within a normal range at baseline and were unchanged with either intervention. For our hypothesis, there was an expectation that muscular and joint restrictions would be present in a population with recurrent neck pain and trigger point deactivation with DN would permit freer movement and increased range of motion. Limited range of motion was not found in this study population. The cervical rotation baseline measures were not considerably different between the DN group (62.4° right, 61.7° left) and the sham procedure (65.1° right, 67.6° left) and both were comparable to normative data (69° right, 66° left). This lack of a cervical mobility deficit in either group at baseline is the likely reason no change was observed with treatment. Importantly for the execution of the Fitts' task, the demands required appear to be well within the abilities of the participants; the

participants exhibit normal range of motion and the furthest amplitude in the head turning task requires 22.6° of rotation. Additionally, the sensitivity and precision of the Fitts' task can be appreciated, with the ability to directly measure function with motor performance outcomes as compared to inferences into function from biomechanical restrictions measured with CROM.

Our results are consistent with two RCTs that found no significant increase in CROM after a DN intervention that targeted active MTrPs (Kamali et al., 2019; Martin-Rodriguez et al., 2019). Kamali and colleagues (2019) recruited a convenience sample diagnosed with tension type headaches with a minimum of three active MTrP (in suboccipital, temporalis, sternocleidomastoid, and/or upper trapezius) and a mean age of 37.45 ± 12.57. The lack of change in CROM could be attributed to the tension type headache diagnosis, as neck stiffness is not a requirement, also caution should be taken with the interpretation of their results because a convenience sample may not represent the general population. Martin-Rodriguez and colleagues' (2019) inclusion criteria was neck pain with one active MTrP in SCM with an age range from 20 - 58 (mean ± SD: 42 ± 12). In this study, improvements in CROM may have been challenging due to normal baseline range of movement apart from limited extension. Both studies exhibit an age spread across multiple decades and proper consideration must be given to age related degenerative changes as real changes in range of motion could have been masked by age. Two other studies confirmed ROM was significantly improved after a DN intervention (Ga et al., 2007; Mejuto-Vazquez et al., 2014). Ga and colleagues (2007) found significant improvements in CROM in an elderly population (mean ± SD: 79.22± 6.8) diagnosed with chronic myofascial pain syndrome of the UT muscle. DN UT was compared to DN UT combined with cervical paraspinals over three treatment sessions for the duration of one week;

baseline measures found limitations in cervical rotation at baseline and all cervical range of motion improved (except for extension in the DN UT group) post intervention. Mejuto-Vazaquez and colleagues (2014) utilized a single session of DN active MTrPs in UT in acute mechanical neck pain with a mean sample population age of 25 ± 4 years and found significant increases in cervical range of motion in the treatment group compared to the no intervention group at both 10 minutes and 1 week after the intervention. Participants in this study had below average baseline range of motion measures compared to normative data. DN has been shown to improve CROM when similar age ranges are studied, and baseline restrictions exist.

The VAS was utilized to determine pain at three time points: baseline, immediately following intervention and at one week follow-up. At baseline, all the participants had low grade pain with a mean of less than three on a VAS. Significant pain reduction was reported from baseline to post-intervention with the difference in raw scores from baseline (2.63 cm) to one-week follow-up (1.53 cm) equaling 1.1 cm. There were no significant between group differences at any time point and overall, there was a mean group difference of less than one. A consensus statement on the VAS for individuals with chronic pain required a 1 cm (10 -20 %) change for MCID and a 2 to 2.7cm (> 50%) change for substantial improvement (Dworkin et al., 2008). With a specific focus on mild to moderate neck pain a reduction in the MCID for VAS was reduced to a change of 0.8 cm (21%) and a change of 2.65 cm (66.8%) for substantial improvement (Lauche et al., 2013). A drop in low-grade pain scores to no pain at all is challenging, nonetheless this study demonstrated a significant and clinically meaningful drop in VAS from baseline to follow up with both interventions.

Similar reductions in immediate pain relief have been reported. A recent systematic review and meta-analysis found DN active MTrPs associated with neck pain was effective in reducing pain immediately (up to 1 week) (MD −1.53, 95% CI −2.29 to −0.76) and in the short-term (from 2 - 12 weeks) (MD −0.51, 95% CI −0.95 to −0.06) compared to sham/placebo/wait list/other needling techniques (Navarro-Santana et al., 2020). The systematic review and meta-analysis conducted by Liu and colleagues (2015) compared wet and dry needling of MTrPs associated with neck and shoulder pain and concluded the DN intervention was effective immediately after (SMD −1.91, 95% CI −3.10 to −0.73) and at four weeks (SMD −1.07, 95% CI−1.87 −0.27) compared to a sham or control procedure. Another meta-analysis of four studies examining DN in the upper quarter recommends DN over sham or placebo for immediate pain reduction (SMD -1.06, 95% CE 0.05 to 2.06) (Kietry et al., 2013). The results from the current study agree with findings from a RCT with a single session of DN to UT MTrPs that found DN decreased neck pain intensity in patients with acute mechanical neck pain, immediately after the intervention and one week after, however the pain was acute (not recurrent) with active MTrPs (not latent) with a waitlist control (not a sham intervention) (Mejuto-Vázquez et al., 2014). Their mean pain values were 5.7 +/- 1.8 pre-treatment, 3.8 +/- 1.9 post treatment and 2.0 +/- 1.7 one-week post with a between group difference of 2.1 (95% CI -0.3-0.8) post treatment and 3.0 (95% CI 2.1-3.9). Another RCT of a population with symptomatic pain in the UT compared superficial DN to deep DN and found significantly less pain immediately following the intervention in both the superficial DN (5.4 [95%CI 4.8-6.32] baseline to 4.60 [95% CI 3.62-5.58] post intervention) and deep DN (5.50 [95% CI 4.68-6.50] baseline and 3.41 [95% CI 2.31-4.52] post intervention) groups (Myburgh et al., 2012). Direct comparisons of the findings from

this study to current systematic reviews and meta-analysis, and independent RCTs are challenging due to heterogeneity in the sample (neck/shoulder, acute/chronic pain, with active/latent trigger points), varying treatment techniques, differing control measures and study designs. That said, our findings are consistent with the current research that both needling interventions changed pain scores at one week follow up.

In the current study pain measures were also utilized to monitor for the confound that DN can be an uncomfortable intervention that has the potential to negatively impact motor performance. Immediately after the intervention, the DN group showed an increase in raw pain values of 0.44 cm that were not present with the sham procedure. Though, the increase in the VAS score did not reach significance and no pain carried over to the one-week follow-up. Current literature does not quantify the amount of pain necessary to causes movement inhibition affecting motor performance. Furthermore, there was no apparent impact of this post-needling increase in VAS scores on motor performance and more specifically, there was no group * time interaction.

A low overall level of neck disability was reported pre-intervention with 58% of the participants reporting no or mild disability. NDI scores were significantly lower over time for both groups, though no between group difference found. Over time this study found a 4-point drop in raw scores from 14.8 to 10.6. A systematic review and meta-analysis on the psychometric properties of the neck disability index found the minimal clinically important difference and minimal detectable change were around 15% (7.5/50 points) (Saltychev et al., 2024), the NDI for chronic non-specific neck sufferers specifically the MDC was 6.9, and the MCID was 5.5 (Young et al., 2017). A recent meta-analysis that found DN active MTrPs had a

positive effect on pain related disability scores in the short-term (1-12 weeks) when compared to sham/placebo/waiting list/other forms of dry needling (SMD −0.87, 95% CI −1.60 to −0.14) (Navarro-Santana et al., 2020). For the current study, a statistical difference was found for the main effect of time, however the requirements for MDC or the MCID for the NDI were not met.

Pressure algometry measurements offer a useful diagnostic tool to quantify abnormal deep muscle tenderness and as a method to document treatment results. The baseline mean PPT of UT were 437 KPa and 434 KPa for the DN intervention and the sham procedure respectively. Baseline values of PPT for UT are heterogeneous in chronic neck pain populations; studies report baseline ranges of 354-403 kPa (Ylinen et al., 2011) and 201-276 kPa (Walton et al., 2011). Fisher and colleagues (1989) recruited fifty-two subjects equally distributed by sex to create normative reference values for muscles that frequently affected by MTrPs. The mean values for the UT were 530 KPa for males and 363 KPa for females. Due to an uneven spread in the data, which favored higher pressures, the author suggested taking 84.1% of the mean scores to represent clinical values: the lowest PPT at which UT could be considered normal was 445 KPa for males and 305 KPa for females. Sciotti and colleagues (2001) conducted a study assessing the precision of four experienced clinicians in locating MTrPs in the UT of volunteer subjects. Manual skills accompanied by patient feedback were used to locate latent MTrPs, the location was documented with 3D camera and the resulting images were compared between all clinicians. Pressure algometry acted as a confirmation of MTrPs by comparing pressure values relative to the MTrP diagnosis. To quantify clinically relevant pressure thresholds the authors compared the thresholds from which there was agreement between the clinicians' diagnosis of latent MTrPs in the UT and the pressures where the MTrPs were markedly responsive. They

found that PPTs less than or equal to 245 KPa captured 47.5% of the group, at 294 KPa captured 62% of the group, at 343 KPa captured 66% of the group, and at 490 KPa captured 80% of the group. Scotti and colleagues (2001) determined a criterion pain pressure threshold of < 343 KPa to detect clinically sensitive latent MTrPs in the UT muscle. For the current study, neither intervention group met this clinical threshold and both group's raw baseline values are within the normative range for UT PPT values.

For recurrent neck pain sufferers lowered PPTs are anticipated due to cervical muscle hypertonicity and muscle hyperalgesia (Sciotti et al., 2001; Ylinen, 2007). Our hypothesis was that DN would reduce the muscle tone and increase tolerance to pressure algometry. We found tolerance to pressure algometry significantly improved with respect to time, and both groups and the left and right sides behaved similarly. Raw PPT mean values improved from 402 KPa to 468 KPa indicating increased tolerance to pressure from baseline to post-intervention with a mean difference of 66 KPa, which falls within a MDC range between 44.5-112 kPa (Walton et al., 2011). A recent systematic review and meta-analysis compared DN to sham/placebo/wait list/other needling techniques found pressure algometry thresholds improve immediately after the intervention (mean difference 55.48 kPa, 95% CI 27.03 to 83.93) (Navarro-Santana et al., 2020). The between groups mean difference in the meta-analysis was likely found due to the testing of active MTrPs with lower baseline PPTs, whereas latent MTrPs are likely to have normal baseline PPT resulting in a reduced range for improvement and ability to differentiate between the two groups.

PPT experimental results show varying responses immediately following DN interventions. Our study found temporal increases in PPT in both interventions and similar

results have been found. A chronic neck pain population was studied to investigate the immediate effects of a single treatment session to a unilateral active MTrP in UT and the effect on local and widespread pain measured by PPT and VAS in three intervention groups (DN, myofascial massage, sham DN) (Stieven et al., 2021). PPTs significantly increased with respect to group and time post intervention in the UT muscle on both the treated and untreated sides in the DN group and myofascial release group, but not in the sham DN group. The findings of significant increase in PPTs at a distant and pain-free location (the proximal head of the radius) supports previous findings of the remote effect of DN (Tsai et al., 2010). This study also found significant reductions in neck pain intensity immediately following the interventions (DN [baseline: 4.50 ± 1.18, immediately post: 2.00 ± 1.07, $p < .001$], myofascial pain [baseline: 4.79 ± 1.19, immediately post: 2.14 ± 1.03, $p < .001$], and sham DN [baseline: 4.71 ± 1.33, immediately post: 4.29 ± 1.44, $p = .008$]) with no adverse treatment pain immediately after or at 72 hours, however only the DN and myofascial pain groups met the MCID.

Other researchers have suggested DN causes local hyperalgesia which may conceal the immediate effects of the intervention (Chys et al., 2023; Myburgh et al., 2012). A RCT with a single treatment session compared DN latent UT MTrPs to a non-penetrating sham at four time points and found there was a reduction in PPTs from baseline (458 KPa +/-98) to the 30 minute (425 KPa +/-91) and 24-hour (386 KPa +/-84) time points, but at 72 hours (509 KPa +/- 113) a significant increase in PPT was revealed (Sánchez-Infante et al., 2021). Needling discomfort during the DN intervention was measured at 30 minutes, 24 hours and 72 hours and found a progressive decrease in post-needling soreness at 30 minutes (33.13 ± 21.31%) compared to 24-hours (80.92 ± 10.06%) with a resolution of the post-needling soreness in all participants at

72-hours. A significant difference in PPT between the groups was observed at 72-hours, this finding suggests that the treatment effect of increased tolerance to PPTs occurred with the resolution of treatment soreness.

Motor Performance Outcomes (MT, Error, PV, PA, ttPV, ttPA, RT)

The Fitts' task offers a well established, very precise objective outcome measure with the ability to capture various motor performance variables. MT, our primary performance outcome, quantifies the displacement time or the duration of time from the movement's initiation to finish. This outcome reflects on the efficiency of the task movement, that is, how quickly the participants complete the task. Our results found both groups experienced similar reductions in MT following their respective interventions, which suggests the participants displayed an improved ability to rotate their head after either intervention. Experimental average MTs were 752 msec. The difference in raw values between the groups was 123 msec, which represents a 16% difference that persisted after the intervention. MTs of both groups improved from baseline to post intervention with a mean change of 52 msec or 7%. These results suggest that the DN and the sham procedure may equally impact MT.

One indicator of poor performance in a Fitts' task is slower movement. Increased MTs have been confirmed in a head aiming task with a chronic neck pain population with low to moderate levels of pain and disability (Descarreaux et al., 2010). Experimentally induced tonic muscle pain can inhibit the motor system (La Pera et al., 2001). The manifestation of central motor command changes are adaptations to motor behavior to avoid pain including reduced muscle activation or altered movement patterns (Holm et al., 2002). Central processing changes

may be accompanied by regional neuromuscular compensations of protective reflexes of inhibition, guarding or splinting to protect from pain or the threat of pain or injury (Hodges and Tucker, 2011; Lund et al., 1991). Alternative movement strategies are consistent with decreased movement efficiency that results in slower movement. A change in central pain processing, where decreased pain perception, results in more confident, less guarded forceful movement with subsequent reductions in MTs may be the result of a DN intervention. Previous research for the efficacy of DN has found pain relief immediately following the intervention and in the short term (Kietrys et al. 2013; Navarro-Santana et al., 2020). Also, the deactivation of latent MTrPs with DN combined with passive stretch resolved the abnormal muscle activation patterns in the shoulder girdle (Lucas et al., 2010). The resulting increased efficiency in movement is consistent with reduced movement times found post needling interventions in the current study.

Fitts law describes the trade-off between speed and accuracy in a discrete aiming task, where speed is limited by the accuracy required. The overall precision of a head turning task depends on the interplay between error (CE and VE) and the target acquisition. CE describes the accuracy of the participants in terms of directional bias and VE describes the consistency of where the participants stopped their movement.

This study's results for the main effect of group and time for CE and VE are as follows. Both groups significantly undershot the target with a difference between the groups of 0.08°. CE significantly improved from baseline to post intervention with an improvement of 0.058°. This suggests the participants moved more accurately after the interventions and may be suggestive of an improved movement strategy. Similar VE between the two groups suggests

there was not a large variation in movement strategies. From baseline to post-intervention there was a significant improvement in VE with a raw score difference of 0.06°. To summarize the reduction in CE and VE post needling interventions suggests movements were performed with more accuracy and less variability.

The evaluation of the target parameters in terms of CE and VE assesses how well the data fit the expected patterns for width and amplitude. Target size did not have a significant effect on participant accuracy, though the distance to the target did significantly impact the accuracy with a mean difference of 0.46° between the first and last amplitude. Participants undershot the target for the first three amplitudes and overshoot the target at the largest amplitude. In terms of VE with respect to target parameters, participants were slightly less consistent for the larger target and less consistent as amplitude increases with mean differences between the widths (0.03°) and the amplitudes (0.2°). The values of CE and VE discussed in terms of main effects and target parameters are very small, and thus were unlikely to impact MTs.

The Fitts' task is an appealing outcome measure because the kinematic variables like PV and PA give insight into the mechanics of movement. Interpreting these variables enables inferences to be drawn about the initial output of the motor plan. Intuitively it could be argued that a person with pain will likely have a slow and careful initial movement strategy, and our hypothesis assumes that after a DN intervention participants will show an increase in PV and PA due to a decreased inhibition to initiate movement. The DN group had higher PV at baseline and tended to increase after treatment, but no such trend was seen in the control group.

Similar results were observed with PA. Additional data collection is needed to draw more definitive conclusions on the effect of DN on PV and PA.

Studying the initial movement strategy (PV and PA) may help clarify the role DN plays in effecting change in a motor performance task. Previous studies in neck pain populations found lower velocity and acceleration during an upper limb task (despite normal range of motion) (Tsang et al., 2007) and lower peak velocities during a head reposition task (Sjolander et al., 2008). The pain adaptation model proposes pain signals interact (in this case from the neck) with motor control centres in the brain and spinal cord and these interactions lead to changes in the sensorimotor output as a reduction in the speed and volume of movement (Hodges and Tucker, 2011). Importantly, the model does not imply that all movement reduction is necessarily accompanied by pain, that adaptations may be adopted to avoid potential pain. The findings in the current study show immediately following the DN intervention VAS scores tended to increase, yet the DN group showed a trend toward increased PV and PA immediately after the intervention compared to no change in the sham group. Here, the DN group exhibited a change in motor performance independent of pain, which suggests that DN triggered a sensorimotor response that altered or reset muscle activation patterns leading to different movement strategies without immediate pain relief.

ttPV and ttPA describe the time taken for the initial ballistic movements to reach their peak. Results found the temporal aspect of PV and PA were no different between the groups and/or the differences were too small to measure with confidence. The time to PV occurs slightly earlier following both interventions. The mean difference in time from pre- and post-intervention was 10 msec, which is right at the limit of the head mouse's resolution of 10 msec,

thus cannot be interpreted with confidence. The results for PA followed the same pattern as PV.

The parameter of RT measures from the onset of the target presentation to movement initiation. Adjustments in movement planning may be reflected in RT. Results showed a significant reduction in RT from pre- to post-intervention for both groups with a raw score difference of 8 msec. A reduction in RT post intervention suggests less time was utilized for motor planning post intervention. RT had significant main effects for both width and amplitude and the raw score differences showed an improvement of 5 and 2 msec respectively. Despite the statistical significance, the differences found in RT cannot be definitively interpreted due to the raw scores being below the head mouse's 10 msec instrument resolution time, thus further investigation is warranted for confirmation.

Fitts Parameters (Width, Amplitude, ID)

Task difficulty, a function of width and amplitude, is an important aspect to investigate the relationship between target characteristics, the dependent variables and how participants adapt and perform the head turning task. This study used two widths and four amplitudes to vary the difficulty of the movement tasks. For MT, the two target widths (1.2 and 1.7 cm) were not significantly different from each other, and the range of difficulty was small (0.5-bit difference in ID). Whereas MT for the target amplitude (range of 8.75 - 25 cm) were significantly different, the distance condition produced a larger range of difficulty (2-bit difference in ID) compared to the width condition. PV and PA had similar results to MT; the amplitudes were statistically different from each other, but the target width condition did not reach significance. ttPV showed a significant main effect of target amplitude, but not width.

ttPA revealed a main effect of both target width and amplitude, but the differences were below the resolution of the system, thus cannot be interpreted with confidence. Overall, the results for target parameters suggest the task conditions were adequately challenging for the parameter of amplitude but were marginal for width.

Assessment of the Blinding

At one week follow up, four questions were asked to assess blinding of group assignment. The first two questions were directed at the experience during the needing: the first quantified the experience in terms of the nature of the pain (i.e. discomfort versus pain) and the second asked whether a muscle spasm or twitch occurred and the third inquired about the duration of discomfort following the intervention. As expected, the sham participants describe a diminished intervention experience compared to the DN group: the median scores for the nature of the pain were 2/7 (compared to 4/7 in the DN group) and median experience of the LTR were 1/7 (compared to 6/7 in the DN group). Significant statistical differences were found for both nature of the pain and the LTR. The question regarding the duration of discomfort following the study was qualitative with the intension of addressing post-needling soreness with options ranging from no discomfort, a few hours, until the next day or greater than one day. The answers for the sham procedure ranged from no discomfort to discomfort for a few hours and for the DN group ranged from a few hours discomfort to discomfort until the following day. No adverse events, beyond muscle soreness, were reported during or after the study. Despite the lack of LTR and brief, if any, discomfort (during or following) the sham intervention, the blinding was effective in terms of rating the treatment as genuine. Statistical

analysis found there was no significant differences between the two groups. This confirms that the perceived validity of the intervention or confidence in group assignment did not significantly differ between the treatment intervention and sham procedure.

Limitations

A recurrent neck pain population was expected to present with deficits in clinical and motor control outcomes. The clinical sample recruited had very minor symptoms, signs and disability which may have prevented observing differences due to the intervention. Clinical assessments and outcomes were included in this study to strengthen external validity. A confounding treatment effect can occur when extensive baseline measurements are taken. For example, repeating cervical range of motion three times in each plane of movement may impact mobility positively, repeated measures of pain pressure thresholds may provide a MTrP release and/or assessing for the presence of MTrPs may introduce neurophysiological input from palpation. Whether the assessment process amounted to a treatment in and of itself cannot be determined in the current study. A pre-treatment effectively reduces the available range from which the treatment efficacy is determined.

In the present study, the two target widths had minimal separation in terms of level of difficulty. To ensure the targeting task was sufficiently challenging for the participants a larger overall range of ID values may have been able to demonstrate an effect of DN on motor performance. Intuitively, we know performance can be impacted by the cognitive demands of the Fitts' task. Lastly, in the present study, the presentation of the target for each trial was

participant controlled, however breaks were not offered or given if the participant was experiencing a loss of focus and/or fatigue.

Future considerations

1. Recruit participant with higher pain and disability levels to reduce the floor effect on the outcome measures.
2. Sham procedures may have potential therapeutic effects due to placebo or expectation of an effect. The addition of a true control/placebo group to measure the potential treatment effect of the assessment and outcome measures and offer insight into cognitive factors, the treatment effect of the lab and interactions with clinicians.
3. An expanded range of ID values could be incorporated into the testing protocol to ensure an appropriate challenge point for the task and the population recruited.
4. A single intervention of DN does not reproduce a clinical intervention. To test a typical clinical intervention the inclusion of multiple sessions and/or augmentation with other interventions (i.e. exercise/education) is necessary.

Conclusion

The clinical measures found significant and clinically meaningful changes for the VAS from baseline to one week post intervention and reductions in PPT for both intervention groups. For the motor performance outcomes, participants had significantly decreased MT accompanied by a significant decreased error rate for both CE and VE, that is, the participants moved faster with more precision. An interesting trend was found with movement initiation, PV

and PA, where after the DN intervention participants' initial movement was faster; this trend was not seen in participants in the sham procedure group.

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