The Effect of Cervical Spine Manipulation on Laterality Judgement Ability in Participants with Persistent Neck Pain

by

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Declaration

This is to certify that this work is entirely my own and not that of any other person, unless explicitly acknowledged by means of citations of published and unpublished sources. The work has not previously been submitted in any form to the Durban University of Technology or to any other institution for assessment or for any other purpose.

8 June 2022

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Approved for final submission

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ABSTRACT

BACKGROUND

Neck pain is among the top twenty most burdensome chronic health conditions worldwide. The severity of neck pain among patients varies, but it has been found that about 50% of episodes tend to become chronic. Previous research has used the accuracy with which the laterality of body parts can be identified as a proxy for cortical body schema accuracy and integrity. Treatments aimed at addressing such cortical maladaptations to pain have been effective in reducing pain and dysfunction in a number of conditions. More specifically, spinal manipulation (SM) has been shown to improve the laterality judgement reaction time (LJRT) of participants regarding alphabetical characters. However, the effect of SM on laterality judgment accuracy (LJA) regarding body parts has not been determined. Moreover, it has been shown that the neurological mechanisms by which the brain determines the laterality of letters and objects (allocentric mechanisms) are distinct from those involved in laterality judgements of body parts (egocentric mechanisms). This study investigated the effects of cervical spinal manipulation on LJA using Neck and Hand images as well as the ‘R’ alphabetical character to determine whether SM was able to address distortions in cortical body schema mapping that may have contribute to persistent neck pain.

AIM

The overarching aim of the study was to determine the immediate effect of cervical spinal manipulation on laterality judgement reaction time (LJRT) and laterality judgement accuracy (LJA) in participants with persistent neck pain.

METHODOLOGY

The study adopted a quantitative paradigm and was a pre-test, post-test experimental trial. People between the ages of 18 and 55 with a current history of non-traumatic neck pain for 4 weeks or more were invited to participate in the study. The selected participants were randomly allocated to either the intervention or the control group. Further screening was conducted by means of a telephonic interview, the elicitation of a medical history, a full physical examination, and a cervical regional examination to ensure that there were no contraindications to their participation in the study. Applicants were excluded if they had received any treatment for their neck pain in the foregoing three months. A total of 58 participants was formally included and randomly allocated to either the intervention or control group. Each participant was then submitted to a pre-intervention/control test for laterality judgment ability in terms of the letter ‘R’ and Hand and Neck images using the commercially available Recognize application. Following the application of the respective interventions (i.e., spinal manipulation and a set up for spinal manipulation without thrust), post-test measurements were taken as before. Each participant also completed a Central Sensitization Inventory (CSI) at the time of participation.

The paired t-tests was used to compare paired means within groups from pre- to post-treatment. Repeated ANOVA measures were used to compare the changes over time between the two treatment groups, while profile plots were used to assess the direction and trend of the effect of the intervention. Correlations between changes in the scores of the alphabetical character ‘R’, Hand, and Neck were assessed using Pearson’s correlation analysis. The same was used to assess the correlation between changes in Laterality judgement performance and CSI scores. These correlations were done for the entire sample regardless of treatment group.

Ethical approval (IREC 013/20) for the study was obtained from the relevant institution’s research ethics committee prior to commencement (Appendix A).

FINDINGS

Both groups showed significant improvements over time between the pre- and post-intervention tests, but improvements in the intervention group were statistically indistinguishable from those of the control group. Additionally, there was no correlation between measures of allocentric and egocentric laterality judgement ability. No relationship was found between CSI scores and laterality judgement performance or improvement over time.

Key words: cervical spine manipulation, persistent neck pain, laterality judgement ability

DEDICATION

This study is dedicated to my Lord and Saviour, Jesus Christ, from whom, to whom, and through whom all things are. This humble work is no exception.

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GLOSSARY OF TERMS

Spinal Manipulation

This is a commonly used treatment modality involving high velocity low amplitude single thrust applied to a joint at the end of the physiological range of motion without exceeding the anatomical limit.

Body Schema

The neurological apparatus that allows for the cognitive mapping and tracking of the body in time and space. The working body schema is as much a pattern of neural firing as a physical arrangement of neurons within the cortex (Wolpert, Goodbody and Husain 1998).

Egocentric

That which centres upon an organism on body or self as a frame of reference. In the context of mental rotation and laterality judgements, it refers to neurological mechanisms that interpret and manipulate objects and scenes with reference to a subject’s own physical body (Iachini and Ruggiero 2006).

Allocentric

That which centres upon something other than the body or self as a frame of reference. Spatial position and orientation are derived from and correspond to something other than the physical body of the subject (Iachini and Ruggiero 2006).

Motor Imagery

The process of mentally rehearsing or simulating a movement without physically performing the action(Dickstein and Deutsch 2007).

Mental rotation

The process involved in imagining the reorientation of an object of a body part into an identifiable position (Shepard and Metzler 1988).

Laterality judgement ability

A form of mental rotation exercise that has been commonly used in scientific settings to measure motor imagery ability in healthy individuals. In these tasks individuals are presented with an image of an object or body part and are required to determine whether the object or body part corresponds to the right or left side of the body or orientation (Boonstra et al. 2012).

LIST OF ACRONYMS:

Acronym	**Full word/phrase**
AAOMPT	American Academy of Orthopaedic Manual Physical Therapists
CNS	central nervous system
CSI	Central Sensitisation Inventory
DALY	disability-adjusted life years
fMRI	Functional Magnetic Resonance Imaging
HVLA	high velocity low amplitude
IASP	International Association for the Study of Pain
IVD	intervertebral disc
LJA	laterality judgement accuracy
LJRT	laterality judgement reaction time
n	sample size
NSNP	non-specific neck pain
SCNP	sub-clinical neck pain
SMT	spinal manipulation therapy
WAD	whiplash associated disorders

CHAPTER 1

OVERVIEW OF THE STUDY

1.1 Introduction and Background

Pain induces neuroplastic changes within the cerebral cortex and these changes are known to contribute to its persistence (Pelletier, Higgins and Bourbonnais 2015). One such possible maladaptive change is a decrease in body schema integrity (Moseley and Vlaeyen 2015), the consequence of which is impaired laterality judgment ability (Bray and Moseley 2011). Previous research has demonstrated that cervical spinal manipulation (CSM) is able to improve mental rotation ability with regard to alphabetical characters (Kelly, Murphy and Backhouse 2000). However, this involves a distinct mechanism that is different from that involving laterality judgements of body part images (Dalecki, Hoffmann and Bock 2012). Further investigation into the effects of spinal manipulation laterality judgement ability (including egocentric mechanisms) in participants with persistent neck pain was warranted by developments within the literature (Dalecki, Hoffmann and Bock 2012; Meyer et al. 2019). It is worth investigating whether CSM has potential as an adjunct tool for addressing cortical maladaptive changes that result from and contribute to persistent pain.

Laterality judgement is the process by which an individual accesses, recognises, and identifies whether a body part belongs to the right- or left-hand side. For instance, inanimate objects or alphabetical characters are presented in their usual (left to right) orientation or in reversed (right to left) orientation. In this study laterality judgement was measured primarily in terms of reaction time while accuracy was a secondary measure. This was done using the commercially available Recognize application as proposed by (Moseley 2004). The application is available on www.noigroup.com.

1.2 Research Problem and Rationale

Although most episodes of neck pain resolve spontaneously, up to 50% of cases become persistent (Cohen 2015). It has been demonstrated that spinal manipulation (SM) is a relatively successful treatment for chronic neck pain (Gross et al. 2015; Coulter et al. 2019), but the precise mechanisms underlying this success are, at best, only partly understood (Randoll et al. 2017; Gevers-Montoro et al. 2021). Maladaptive neuroplastic changes within the cerebral cortex are now known to play a significant role in the exacerbation and persistence of pain and sensorimotor dysfunction (Pelletier, Higgins and Bourbonnais 2015). Moreover, imprecision of neural signatures pertaining to pain and the body schema is a significant contributor to persistent pain (Moseley and Vlaeyen 2015). Laterality judgements require individuals to mentally rotate their own body part (according to biomechanical constraints) to correspond with that part in question (Vannuscorps, Pillon and Andres 2012) (Meng et al. 2017) Meng and, on this basis, laterality judgement tasks have been used as a proxy to access the functional integrity of the body schema (Bray and Moseley 2011). Research interest has increasingly been directed towards therapies with the potential to target the cortical aspects of nociplastic pain (Moseley 2004; Cacchio et al. 2009; Swart, Stins and Beek 2009; Moseley and Flor 2012).

In addition to pain relief, it has been shown that spinal manipulation positively affects cortical processing and spatial awareness of body parts (Haavik and Murphy 2011; I. Niazi 2013). Previous research has also demonstrated that spinal manipulation has a beneficial effect on laterality judgement reaction time with regards to the alphabetical character 'R' in cases of subclinical neck pain (Kelly, Murphy and Backhouse 2000) . Research has also demonstrated that the mental rotation of letters involves an 'allocentric' cortical mechanism in which a reference point external to one's own internal body schema is utilised (Kelly et al. 2000). Mental rotations involving body parts, on the other hand, are based upon an egocentric cortical mechanism which is based upon the body schema as a reference point (Dalecki, Hoffmann and Bock 2012).

This study investigated the effects of spinal manipulation on egocentric and allocentric mental rotations involving the body schema. Current pain neuroscience findings point towards this as a contributing factor to persistent pain (Pelletier, Higgins and Bourbonnais 2015). Moreover, the study also applied laterality judgement accuracy as a measurement utilising a population sample that presented with symptomatic persistent neck pain.

The literature review proposed that, whilst the findings of the study by Kelly et al. (2000) were promising, ongoing developments in the fields of pain neuroscience, mental rotation, and spinal manipulation warranted further investigation into the effects of spinal manipulation on laterality judgement ability. Discoveries in pain neuroscience now highlight the potential clinical value of improving egocentric laterality judgement ability. Given that spinal manipulation has been shown to improve allocentric laterality judgements, a further investigation into the effects of spinal manipulation on egocentric laterality judgement ability was required, which was a gap that the current study attempted to fill. Although laterality judgement accuracy impairment has been associated with chronic neck pain, to date no study has investigated the effects of spinal manipulation for laterality judgement accuracy for either allocentric or egocentric measures, nor have the effects of spinal manipulation on laterality judgement reaction time been investigated in a population presenting with clinical neck pain.

1.3 Aim of the Study

The study aimed to determine the immediate effect of cervical spinal manipulation on laterality judgement reaction time (LJRT) and laterality judgement accuracy (LJA) in participants with persistent neck pain.

1.4 Objectives

The objectives of the study were to determine:

1. Whether either the control or the intervention group exhibited a statistically significant improvement in LJRT and/or LJA between pre- and post-test measures using a paired t-test comparison of the pre- and post-test means.
2. Whether the intervention group exhibited a greater mean improvement in LJRT and LJA (for each measure) compared to the control group by conducting an unpaired t-test to confirm whether any relative improvements were statistically significant.
3. Whether improvements in LJRT and LJA for egocentric laterality judgement tasks (hand and neck images) were equal to or distinct from improvements in LJRT and LJA for allocentric laterality judgment tasks ("R") and to evaluate the statistical significance of any such differences using a paired t-test.
4. The extent to which LJA and LJRT performance correlated with Central Sensitisation Inventory scores.

1.5 Hypotheses

1.5.1 Null hypothesis:

Cervical spinal manipulation will not lead to a statistically significant improvement ($p<0,05$) in laterality judgement reaction time and accuracy in the experimental group participants as compared to the control group.

1.5.2 Alternative hypothesis:

Compared to the control group, cervical spinal manipulation (CSM) in the experimental group will lead to a statistically significant ($p<0,05$) improvement in laterality judgement reaction time in participants with persistent neck pain.

1.6 Structure of the Thesis

This thesis is presented in six chapters. The introduction (Chapter 1) will be followed by the literature review in Chapter 2, in which the relevant body of literature on this topic will be discussed. A detailed explanation of the methodology that was employed will follow in Chapter 3 which will outline the materials and methods used to structure the design of this research. The key results will be presented in Chapter 4 and Chapter 5, which are the analysis and discussion chapters. The discourse in these chapters will explained how these results addressed the aim and objectives of the study. In Chapter 6 relevant conclusions are drawn and recommendations are offered based on the findings of the study.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter will detail academic literature that was found relevant to the topic under investigation. The anatomy of the cervical spine will be described with particular focus on neuroanatomical structures. An overview of most recent research related to persistent neck pain will be presented. In addition to an illumination of spinal manipulation, consideration will also be given to research findings in the field of pain neuroscience as well as the areas of mental rotation and laterality judgements.

2.2 Anatomy of the Cervical Spine

The osseous structures of the cervical spine include the 7 cervical vertebrae which are the smallest of the spinal vertebrae. Each vertebra is named according to its numerical position counting inferiorly from the occiput such that C1 is most proximal and C7 most distal. These 7 vertebral segments are naturally arranged into a lordotic curve. A 'normal' measurement of the degree of this lordosis according to the C1-C7 Cobb method has been routinely reported as 35° - 45° in reputable text books (Yochum 1987). However, research has demonstrated average lordosis curve measurements in asymptomatic adults to be 21,3°and 22,3° respectively (Gore, Sepic and Gardner 1986). Moreover, a small but significant population of asymptomatic adults has been shown to present with kyphotic cervical segments (Gore, Sepic and Gardner 1986). Whilst the reality of this sub set must be given serious consideration in regards to any discussion of a normal lordotic curve measurement, it does not necessarily follow that kyphotic cervical segments are a normal or optimal variant either (Harrison, Harrison and Haas 2002).

Whilst C3-C6 are classified as typical, C1, C2 and C7 are considered atypical due to their variation in structure. Except for C1, each vertebra is made up of an anterior vertebral body as well as a posterior arch. The channel which runs between the body and the arch is known as the vertebral canal within which the spinal cord is located.

2.2.1 Typical cervical vertebrae

C3 to C6 are considered to be typical cervical vertebrae as they have five hallmark characteristics. The vertebral bodies are noticeably flattened with a greater dimension in the transvers plain compared to the coronal and sagittal. The superior surfaces of the vertebral bodies are concave whilst the inferior are convex. In order to facilitate translation in the transvers plain, the superior facet joints face superiorly and posteriorly and the inferior facets are angled inferiorly and posteriorly. The intervertebral foramen is large in relation to the size of the vertebral bodies. Spinous processes are comparatively short as opposed to those found in thoracic and lumbar regions (Moore, Dalley and Agur 2014).

2.2.2 Atypical cervical vertebrae

The remaining cervical vertebrae, C1, C2 and C7, are referred to as the atypical vertebrae. C1, also known as the atlas, is unique in that it is made up only of the anterior and posterior vertebral arches without a vertebral body. The right and left lateral masses each support a superior and inferior facet joint and these joints articulate with the occiput and the superior facet joints of C2 respectively. The posterior surface of the anterior vertebral arch articulates with the anterior aspect of the odontoid process of the C2 vertebra below.

The second cervical vertebra is also known as the Axis and its most distinct feature is the odontoid process. This feature extends in the cephalad direction from the C2 vertebral body and articulates with the posterior surface of the anterior arch of the atlas. The process is held in place by the cruciate ligament to form a pivot joint which facilitates increased rotational range of motion at this level.

The seventh cervical vertebra is unique in that it has a non-bifid and relatively prominent spinous process. The transverse processes are also relatively large and have noticeable smaller (or absent) transverse foramina in relation to the typical cervical vertebral (Moore, Dalley and Agur 2014).

2.2.3 Articular structures

Typical cervical vertebrae form three articulations with the vertebrae directly superior and inferior. The intervertebral disc (IVD) exists between the adjacent vertebral bodies while the right and left facet joints form the articulations between the posterior arches.

2.2.4 Intervertebral discs (IVDs)

The primary function of the IVDs is the transfer and dissipation of spinal loading between adjacent vertebrae (Walter BA 2015). They form the primary intervertebral articulation and contribute as much as one third of the total height of the spine. Each IVD consists of a tough fibrous outer layer known as the annulus fibrosis. Each of the 15-25 concentric layers of the annulus is made up of highly organized collagen fibres which run at angles approximately 60° to the sagittal plain with each adjacent layer alternating either to the left or right. The nucleus pulposus lies centrally within the disc and contains randomly organized collagen fibres and radially orientated elastin fibres. These fibres are embedded within an aggrecan-based gel which provides a rubbery, elastic-like quality to the structure (Raj 2008).

2.2.5 Facet joints

Facet joints, also known as zygapophyseal joints, are diarthrodial joints of the posterior vertebral arch of the cervical spine. Two facet joints (right and left) articulate with the vertebrae above (superior articular facets) and below (inferior articular facets) each individual vertebra. The facet joints facilitate a greater degree of movement (Mow, Ateshian and Spilker 1993) although they are also required to tolerate significant loading (Sperry et al. 2017). As synovial joints, the two opposing surfaces are lined with a layer of hyaline cartilage surrounded by a synovium and fibrous capsule. Congruency of the two surfaces is aided by meniscus-like structures (O'Leary et al. 2018).

2.3 Neuroanatomy

The vertebral canal of the cervical spine contains the cervical portion of the spinal cord as it conveys the various spinal tracts from the medulla oblongata of the brain stem inferiorly to the rest of the body. The chord possesses a cervical enlargement which runs from approximately the level of C3 until T1. This bulge is made up of segments from C3 to T1 and supplies innervating structures to the upper limb via the brachial plexus (Crossman and Neary 2005). The cord itself is partially divided into separate halves by the dorsal median sulcus and the ventral median fissure. The central canal facilitates the passage of cerebrospinal fluid along the length of the cord and is joined with the cerebral ventricular system superiorly (Crossman and Neary 2005). The innermost portion of the cord consists of spinal grey matter made up of cell bodies. White matter, which contains afferent and efferent nerve fibers, makes up the outer portion.

These fibers are grouped together into tracts that function together to convey nervous impulses between specific areas of the CNS and somatic structures. The two primary ascending tracts are the Dorsal Column and the Spinothalamic tract. The Dorsal Column System conveys sensory information which the brain interprets to facilitate proprioception and discriminative touch. The spinothalamic tract carries nervous impulses related to pain, temperature sensation, and course touch. The major descending spinal tracts are the corticospinal tract which conveys information related to voluntary motor control, the rubrospinal tract which helps regulate involuntary muscle tone, and the tectospinal tract which is thought to play a role in facilitating reflex movements in response to visual stimuli (Crossman and Neary 2005).

The cervical spine contains 8 pairs of spinal nerves that convey afferent and efferent impulses between the central and peripheral nervous systems. The superior most cervical nerve, C1, is located in the vertebral canal above the level of the C1 vertebra. Each subsequent spinal nerve exits above its corresponding vertebral body until C8, which runs through the vertebral foramina between C7 and T1. These spinal nerves themselves are formed by the confluence of the dorsal and ventral nerve roots that emerge from the spinal cord and converge in or near the opening of the intervertebral foramen (Moore, Dalley and Agur 2014).

2.3.1 Innervation of facet joints and intervertebral discs

2.3.1.1 Intervertebral disc innervation

Healthy IVDs receive relatively little innervation (Garcia-Cosamalon et al. 2010). The innervating structures that are present are derived from branches of the sinuvertebral nerve, offshoots of the ventral rami of the spinal nerves, as well as derivatives of neural plexuses found within the anterior and posterior common vertebral ligaments (Suseki et al. 1998). These innervating structures then receive afferent inputs from terminal structures found in perivascular nerves, mechanoreceptors, and sensory nerve endings that are independent of blood vessels (Groh et al. 2021).

2.3.1.2 Facet joint innervation

The facet joint capsules are innervated by two medial branches of the dorsal rami. Each facet joint receives innervation from the levels above and below it so that that the facet joint between C4 and C5 is innervated by the medial branches from C4 and C5 (Kallakuri et al. 2012). Changes to the state of the joint capsule and articular structures generate specific action potentials within respective innervating structures which, in turn, convey afferent neuronal signals to the central nervous system (Jaumard, Welch and Winkelstein 2011).

Wyke (1966) groups the articular receptors into four distinct categories. Type I receptors are characteristically low threshold, slow adapting mechanoreceptors. These respond to mechanical tension within the joint capsule and in this way there is a portion of Type I receptors that is active in every joint position of the joint regardless of whether the joint is mobile or immobile.

Type II is found predominantly within the superficial layers of the fibrous tissue of the joint capsule. Like Type I, Type II requires a low threshold for stimulation; however, Type II receptors are rapidly adapting and, as such, they only become active upon the initiation and cessation of joint movement. These receptors are thus inactive while a joint is immobile. Type II receptors are primarily stimulated by the experience of acceleration or deceleration of a particular joint.

Type III receptors are not found in the facet joints; rather, they are limited to the extremities. Type IV receptors are responsible for articular nociception and are completely inactive unless the articular tissues are exposed to significant mechanical deformation and/or direct chemical or mechanical irritation (Wyke 1966).

2.4 Persistent Neck Pain

2.4.1 Epidemiology

Neck pain is a significantly burdensome musculoskeletal condition (Vos et al. 2012) with between 30 – 50% of cases becoming persistent (Cote et al. 2004; Cohen 2015). In any given year, between 10.04 – 21.3% of the population will experience some form of neck pain (Hoy et al. 2010) and recent research has found that these incidences are higher in people who perform computer and office work than in those who do not (Hoy et al. 2010). Neck pain has also been associated with the use of mobile devices for extended periods of time (Blumenberg et al. 2021). It has also been suggested that over half the global population will experience neck pain at some point in their lives (Cote, Cassidy and Carroll 1998). After back pain, neck pain has been found to be the greatest musculoskeletal contributor of disability-adjusted life years (DALYs) (Murray et al. 2012). It has also been found that the prevalence of neck pain is higher amongst women and that the peak prevalence tends to be around middle age (Hogg-Johnson et al. 2008).

2.4.2 Pain

The International Association for the Study of Pain (IASP) (1994) defines pain as "...an unpleasant sensory and emotional experience associated with, or resembling that which is associated with, actual or potential tissue damage". Although unpleasant, pain plays an important teaching and protective role for sentient organisms. Rare congenital abnormalities that render individuals incapable of experiencing pain cause them to be in significant danger of life threatening injury (Basbaum et al. 2009). Thus acute pain is necessary for learning to Recognize and ovoid dangerous objects and behaviours. The aversive nature of pain produced by a serious tissue injury encourages immobilisation and protective behaviours that prevent further injury and promote healing (Fields 1999; Johansen and Fields 2004). However, certain forms of chronic pain, such as neuropathic pain, are considered to be maladaptive and are currently understood to have only negative effects on people's wellbeing and quality of life (Costigan, Scholz and Woolf 2009). The IASP breaks down neuropathic pain into either/or pain due to maladaptation of the peripheral somatosensory system or the central somatosensory system (IASP 1994).

2.4.2.1 Peripheral paradigm of pain

Traditionally, the treatment for neck pain has been informed by a structural pathology paradigm which assumes that the source of pain is localized at the site of pain (Pelletier, Higgins and Bourbonnais 2015). This approach considers pain to be largely, if not entirely, the result of nociception. Nociception is the term used to describe the detection of intense thermal, mechanical and/or chemical stimuli by specific nerve fibres known as nociceptors (Ossipov 2012).

Although often successful in regard to the treatment of acute pain, there are aspects of persistent pain that prove problematic for a model that focuses on "end organ dysfunction" (Wand et al. 2011). More specifically, this conception is challenged by the poor correlation between pain and diagnostic imaging (Stadnik et al. 1998), the presence of bilateral radiographic findings in patients with unilateral symptoms (Tempelhof, Rupp and Seil 1999), and the common reality of asymptomatic patients with significant structural tissue damage and/or injury (Teresi et al. 1987). Although, perhaps the most well-known example is the discord between clinical symptoms and radiographic findings in regards to osteoarthritis of the knee (Bedson and Croft 2008). A similar lack of correlation has been found between radiological indicators of cervical joint disease and clinical symptoms, including self-reported pain levels (Rudy et al. 2015). Moreover, the structural pathology approach is insufficient for understanding why some patients recover from acute musculoskeletal injuries whilst others go on to develop chronic pain despite resolution of the initiating tissue damage (Modic et al. 2005).

2.4.2.2 Cortical, neuroplastic paradigm of pain

In contrast to the above, a considerable body of research suggests that nociception itself is neither necessary nor sufficient for the experience of pain (Wall PD 1986; Melzack R 1988; Butler D 2013). Whilst nociception commonly plays an important role, it is now understood that pain is a conscious experience mediated by numerous neurological and cognitive factors (Moseley and Vlaeyen 2015).

Throughout the life span of humans, the brain retains its ability to undergo functional and structural changes (Pascual-Leone et al. 2005). The understanding of the brain's capacity to adapt to changing stimuli, known as neuroplasticity, is playing a formative role in guiding approaches to somatosensory rehabilitation following neurological injury (Westlake and Byl 2013). A growing body of evidence also suggests that chronic musculoskeletal pain disorders are not limited to the joint itself, but include aspects of central nervous system maladaptive reorganisation (Roy et al. 2017). Studies in animals have shown that peripheral nerve injuries in primates are able to produce adaptive alterations to those parts of the cerebral cortex associated with sensorimotor somatotopy

(Wall et al. 1986). Comparable findings have been produced in human studies that have demonstrated that phantom pain is strongly correlated with changes in the cortical body schema (Flor et al. 1995). Chronic lower back pain has also been shown by structural MRI to be associated with an altered volume of grey matter in the brain compared to healthy controls (Baliki et al. 2011). This latter research also demonstrated that unique chronic musculoskeletal conditions produced distinct changes within the CNS (Baliki et al. 2011).

Pain and dysfunction of somatic or visceral structures result in neuroplastic changes within the central nervous system (CNS) (Baliki et al. 2011; Boadas-Vaello et al. 2017). Instances of aberrant cortical function have been documented by functional Magnetic Resonance Imaging (fMRI) in numerous chronic pain conditions such as spinal pain, fibromyalgia, and complex regional pain syndrome (Do Hyung Kang. 2010; Davis and Moayedi 2013). These neurological changes are the result of afferent nociceptive and neuropathic stimuli to the central nervous system. In a chronic state, although they can be initially beneficial, these afferents may become contributors to the pathophysiology of chronic pain (Pelletier, Higgins and Bourbonnais 2015). Researchers are even proposing that these plastic changes within the brain may be central to understanding the transition from acute to chronic pain (Apkarian, Hashmi and Baliki 2011).

There are no specific cell types or brain regions that are designated exclusively to the pain experience (Basbaum et al. 2009). As a result, the sensation of pain likely results from the highly refined interchange between neurons in diffuse cortical and subcortical areas (Kucyi and Davis 2015). Whilst this complex interconnectedness of neural firing patterns or ‘signatures’ is not yet well understood, the sensorimotor cortex is known to show patterns of activity during the experience of pain (Mazzola et al. 2009; Garcia-Larrea 2012; Frot et al. 2013). It is noteworthy that this area is involved in multiple complex cortical processes involving planning and execution of somatic motor functions and is related to the homunculus both anatomically and functionally.

One possible form of maladaptive changes with the central nervous system is the ‘blurring’ of synaptic pathways related to the cortical homunculus, or body schema. Imprecision of neural signatures pertaining to pain and the body schema has been theorised to be a significant contributor to persistent pain (Moseley and Vlaeyen 2015). The possibility of body schema distortions may explain why chronic pain is associated with impaired proprioceptive ability (Hush et al. 2011; Stanton et al. 2016). Numerous studies have demonstrated that individuals with chronic pain have a distorted perception of the size, shape, and orientation of the associated body parts (Lewis et al. 2007; Lotze and Moseley 2007; Moseley 2008). Considerable evidence for this hypothesis is found in the fact that repeated studies have found that virtual reality distortions of perceived body position are able to modify the experience of chronic pain (Preston and Newport 2011; Llobera et al. 2013; Gilpin et al. 2015).

2.5 Laterality Judgement Ability and Mental Rotation

2.5.1 Mental rotation

Mental rotation is performed whenever an individual is required to identify stimuli that are presented to them at different angulations and/or orientations. We know this because the time taken to Recognize a rotated object is directly proportional to the degree of angulation from the most Recognized position (Shepard and Metzler 1988). Motor imagery is a similar term used to describe the process of mentally rehearsing or simulating a movement without physically performing the action (Dickstein and Deutsch 2007). Laterality judgement tasks are a form of mental rotation exercise and have been commonly used in scientific settings to measure motor imagery ability in healthy individuals (Boonstra et al. 2012). In these tasks individuals are presented with an image of an object or body part and required to determine whether the object or body part corresponds to the right or left side of the body or orientation. In clinical settings such laterality judgment tasks have become increasingly used as both an evaluative and therapeutic tool in patients with chronic pain (Schwoebel et al. 2001) and functional movement deficits (Helmich et al. 2007; de Vries et al. 2013; Kemlin et al. 2016).

The brain is constantly maintaining an internal representation of our bodies in time and space. This complex task is performed using a number of cortical ‘body maps’ that include body surface, visual fields, as well as vestibular and primary motor maps. In this sense the working body schema is as much a pattern of neural firing as a physical arrangement of neurons within the cortex (Wolpert, Goodbody and Husain 1998). In addition to facilitating the coordinated movement of body parts during the performance of psychomotor tasks, the body schema is also engaged during observation and imagination of such activities. These somatosensory neurons, which fire during passive observation or imagination, are referred to in the literature as mirror neurons and were first discovered in monkeys in 1992 (Cook et al. 2014). Subsequently, these neurons have been demonstrated to be present and active in human brains as well (Molenberghs, Cunnington and Mattingley 2012). In essence, when we are presented with an image of a hand (or other body part) and asked to identify its laterality (whether it is a right or left hand), the brain imagines moving the hand into a recognisable position (Vannuscorps, Pillon and Andres 2012; Meng et al. 2017). Positron Emission Tomography has been used to demonstrate the activation of the same brain pathways in both actual movement and imagined movement during these hand recognition tasks (Parsons and Fox 1998; de Lange, Hagoort and Toni 2005). As such, the body schema is similarly involved in both actual and imagined movements. In this way tasks that require imagined movements can be a useful way of accessing the effect of pain on the integrity of the body schema (Schwoebel et al. 2001; Funk, Shiffrar and Brugger

2005). A working body schema is required to make fast and accurate left/right decisions regarding body parts (Parsons 2001).

Evidence for the use of mental rotation/imagery in the performance of laterality judgement tasks is largely based on two common findings. First, there is a linear relationship between reaction times and the size of the angle at which the object or body part is rotated (ter Horst, van Lier and Steenbergen 2010; Blasing et al. 2013). Secondly, with regards to hand images, reaction times are consistently slower for images in which the hand is rotated laterally with fingers pointing away from the body as opposed to those with fingers pointing towards the body. This is thought to be due to biomechanical constraints that make it more difficult to rotate hands laterally than medially. This of course suggests that mental motor imagery is limited by physical biomechanical factors (Sekiyama 1982; Parsons 1987).

Research by Dalecki and co-authors has called into question the possibility that mental rotation of inanimate objects such as alphabetical letters may not involve the same neurological mechanism as that involving body parts (Dalecki, Hoffmann and Bock 2012). Subsequent to the conceptualisation and approval of this study, a notable study was published that challenged the well-entrenched assumption that laterality judgments necessarily involve mental imagery but that some individuals make use of alternative strategies, including visual mental rotation (which is unrelated to biomechanical constraints) or simple comparisons of figure shapes without rotation (Mibu et al. 2020).

2.5.2 Laterality judgement ability, mental rotation, and neck pain

Baarbe, Homles, Murphy, Haavik and Murphy (2016) found that individuals (n=26) with subclinical neck pain (SCNP) had impaired laterality judgment reaction time in regard to alphabetical characters compared to a healthy control group. A 2014 case-controlled study (Elsig et al. 2014) found that participants with neck pain (n=60) had reduced laterality judgement accuracy regarding neck images compared to the in the control group. Additionally, LJA scores correlated with both the neck disability index and avoidance beliefs scores. In 2010 another study was conducted using healthy controls (n=22) to interrogate the laterality judgement ability (hand images) for 24 participants with non-specific neck pain (NSNP) and 21 participants with whiplash associated disorders (WAD). No difference was found between the NSNP and control the group while the WAD group showed marginally faster reaction time and increased accuracy (Richter et al. 2010). Another study (n= 64) demonstrated that chronic whiplash associated disorders were not associated with laterality judgment impairment (Pedler, Motlagh and Sterling 2013:76). Each of these cited studies used different measures of LJA and LJRT. Elsig et al. (2014) used only neck images, Pedler et al. (2013) used neck and foot images, while Richter et al. (2010) used only hand images.

Two meta-analysis and systematic reviews were published on this broad topic (Breckenridge et al. 2019; Ravat S Pt et al. 2020). Breckenridge et al (2019) compared the results of the studies by Elsig et al. (2014), Pedler et al. (2013), and Richter et al. (2010) and found no difference in laterality judgement performance between individuals with chronic neck pain and health controls. The study by Baarbe et al. (2016) was not included in the analysis. Close scrutiny revealed that their conclusions were oversimplified as no differentiation was made between cases of traumatic and non-traumatic neck pain. Given that Richter et al. (2010) found the WAD group to have improved laterality judgement performance relative to heathy controls, a proper analysis may separate the cases of NSNP and WAD into related categories. Therefore, as the best available evidence suggests that WAD and non-specific neck pain have distinct effects on laterality judgement ability, meaningful conclusions can only be reached based on a separate analysis of the evidence for each of these conditions.

Ravat et al. (2020) concluded that there was “conflicting evidence” for laterality judgement impairment in individuals with non-specific neck pain based on their analysis of the studies by Elsig et al. and Richter et al. It is important to acknowledge, however, that these two studies are not directly comparable as they used different measurements of laterality judgement. Elsig et al. (2014) used images of the “left or right side of the body” and measured only accuracy (Elsig et al. 2014) while Richter et al. (2010) measured both reaction time and accuracy but only for images of the hand (Richter et al. 2010). In light of this it is not unreasonable to suggest that there is currently insufficient evidence to justify the assertion of conclusions on the level of systematic review and meta-analysis given the variation of sample population characteristics and measured variables within the availably studies.

It is also noteworthy that neither Ravat et al. (2020) nor Breckenridge et al. (2019) included Baarbe et al. (2016) in their analysis. Breckenridge et al. (2019) made no mention of the latter study while Ravat (2017) had earlier cited Dalecki et al. (2012) to argue that Baarbe et al. (2016) ought not to be included in a review of laterality judgement. This argument by the former authors was based on the notion that tasks involving the letter ‘R’ are not “a true representation of body schema” as they involve an allocentric as opposed to egocentric mechanism (Dalecki, Hoffmann and Bock 2012; Ravat 2017)(Dalecki, Hoffmann and Bock 2012).

2.6 Spinal Manipulation

2.6.1 Clarification of terms

The therapy known to chiropractors as ‘spinal manipulation’ or ‘spinal adjustment’ is a commonly used treatment modality by numerous manual therapists including chiropractors, osteopaths, physicians, and physiotherapists, although there is some variation in the referent language used within each field. For instance, where the physiotherapy literature makes use of ‘grade V spinal mobilisation’, the osteopath community speaks of ‘high velocity low amplitude (HVLA) thrust manipulation’ (Puentedura 2018). These differences in terminology have led to some confusion about the distinctiveness of the technique. In an effort to provide clarity and to standardise terminology, an American Academy of Orthopaedic Manual Physical Therapists (AAOMPT) task force suggested the following six criteria by which a manipulative technique can be described: (i) rate of force application, (ii) location in range of available movement, (iii) direction of force, (iv) target of force, (v) relative structural movement, and (vi) patient position (Mintken et al. 2008).

Perhaps the best explanation of what differentiates the chiropractic spinal manipulation from other is provided by Maitland (1986) who argues that, whilst mobilisation is understood to involve low velocity repetitive, passive movements of the patient’s spine, chiropractic manipulation is applied as a singular thrust applied at a rapid rate. As such it is not the force but the rate or velocity of the intervention that is unique to manipulation (Maitland 1986).

2.6.2 Fixation: The target lesion of spinal manipulation therapy

A fixation is defined as “a state of reduced or suboptimal articular function between one or more articulating structures” (Gatterman 2005). With regards to the cervical spine, we refer to fixations as motion restrictions between adjacent vertebrae within a motion segment. Motion segments are made up of adjacent vertebrae as well as their respective connective tissues (Leach 2004; Gatterman 2005). These restrictions are usually, but not always, correlated with muscular tightness and tenderness (Degehardt et al. 2005). In her book *The Reality Check*, Heidi Haavik (2018) points out that such restrictions are often associated with reduced neurological functioning.

2.6.3 Spinal manipulation and its effect on pain

A systematic review and meta-analysis (Coulter et al. 2019) found that spinal manipulation was effective in reducing pain and improving function in chronic non-specific neck pain relative to alternative interventions. Another review that was conducted on behalf of the Cochrane Database found that a single session of cervical spinal manipulation was able to produce immediate pain relief and that multiple sessions were able to sustain this pain reduction over the short and medium terms (Gross et al. 2015).

Although the pain relieving properties of spinal manipulation have been well documented, the exact mechanism by which this takes place is still unclear. Although a number of studies have demonstrated that spinal manipulation is able to produce analgesic effects and alter pain perception (Bialosky et al. 2008; Bialosky et al. 2009; Bialosky et al. 2014; Gevers-Montoro et al. 2021; Provencher et al. 2021), the specific mechanism by which it does so is at best only partly understood (Randoll et al. 2017; Gevers-Montoro et al. 2021).

2.6.4 Spinal manipulation and the nervous system

In addition to relieving symptoms of pain and discomfort, spinal manipulation is able to affect the central nervous system (M. 1975; Leach 2004; Gatterman 2005; Nolan 2010; Pickar and Bolton 2012). SMT has been demonstrated to influence visual fields (Carrick 1997), joint position sense (Haavik and Murphy 2011; Holt 2014), reaction times (Kelly, Murphy and Backhouse 2000), brain processing (Haavik-Taylor and Murphy 2007), spinal cord reflex excitability ((Murphy, Dawson and Slack 1995); (Herzog, Scheele and Conway 1999); (Suter et al. 2000), balance (Nolan 2010), and cortical and cerebellar motor processing (Daligadu et al. 2013).

2.6.5 Spinal manipulation and mental rotation

To date there has only been one other publicly available study on the effects of spinal manipulation on mental rotation or laterality judgement ability. Kelly et al. (2000) conducted a pilot study in the publication year based on their investigation into the effects of spinal manipulation using laterality judgement reaction time with regards to the letter 'R'. More specifically, they included images of either regular 'R's or reversed (mirror image) 'R's. This prospective, double-blind, randomised, controlled trial had a sample size of 18 for each of the two groups all of which were reported as having subclinical neck pain. The results showed a statistically significant greater improvement in reaction time in the intervention group (98ms) compared to the control group (58ms)(Kelly, Murphy and Backhouse 2000).

Whilst this study showed promising results for the efficacy of spinal manipulation on improving cortical processing, it was limited in that it investigated only improvement in reaction time and not accuracy, and also considered only mental rotation of alphabetical characters and not body parts. Subsequent research has shown that mental rotation of letters involves distinct cortical mechanisms (allocentric) compared to those involved in laterality judgments of body parts (egocentric) (Dalecki, Hoffmann and Bock 2012).

Participants were also recruited from the campus of a chiropractic college and were thus unlikely to be appropriately disinterested. Moreover, the study involved subclinical neck pain that was defined as having “evidence of upper cervical subluxation, as determined by static and motion palpation procedures”. As such many, if not all, of the participants may well have been asymptomatic. Meyer et al have pointed out the potential difficulty which arises from the uncertainty of how subclinical participants differ from the healthy population. In order to make sense of the claim that spinal manipulation is able to improve brain function then it must first be established what the deficit is that needs to be improved upon (Meyer et al. 2019).

Whilst the study by Kelly et al. (2000) was promising, ongoing developments in the fields of pain neuroscience, mental rotation, and spinal manipulation warrant further investigation into the effects of spinal manipulation on laterality judgement ability. Discoveries in pain neuroscience have recently highlighted the potential clinical value of improving egocentric laterality judgement ability. Given that spinal manipulation has been shown to improve allocentric laterality judgements, further investigation into the effects of spinal manipulation on egocentric laterality judgement ability seems pertinent. Although laterality judgement accuracy impairment has been associated with chronic neck pain, to date no study has investigated the effects of spinal manipulation for laterality judgement accuracy for either allocentric or egocentric measures. Nor for that matter have the effects of spinal manipulation on laterality judgement reaction time been investigated in a population presenting with clinical neck pain. It was this gap in research that the current study endeavoured to fill.

CHAPTER 3
CONCEPTUAL FRAMEWORK

3.1 Introduction

This chapter will detail the procedural issues that were adopted to conduct this study. The discussion will commence with an explanation of the study design and continue to elucidate participant recruitment, decisions regarding sample size, inclusion and exclusion criteria, and participant randomisation into either the intervention or control group. The intervention and control procedures will be outlined and the measurement tool will be described in detail. The statistical analysis methods that were employed will also be discussed.

3.2 Study Design

This study was designed within the quantitative paradigm. It was a pre-test, post-test experimental trial involving the random allocation of participants into either the intervention or control group. In this type of study design the researcher applies an intervention and observes its effects on an experimental group. These effects are compared with those of a control group that does not receive spinal manipulation but rather a physiological control intervention. This design is preferable to an observational study in that it is able to demonstrate the degree of probability of casualty, while the randomization of participants minimises the effects of confounding variables (Hulley et al. 2013)

As the research question that was addressed was premised upon the hypothesis that cervical spinal manipulation (CSM) increases the accuracy with which individuals with persistent neck pain are able to make laterality judgements, it was essential that the study design was able to demonstrate or refute a high probability of causation. In light of this a randomised controlled trial is best suited to address this particular research problem (Scriven 2008).

3.3 Location of the Study

This study was conducted at the Chiropractic Day Clinic of the Durban University of Technology (DUT) as well as at mobile treatment clinics attended by DUT chiropractic students as supervised by clinicians from the DUT Chiropractic Day Clinic. Permission to conduct this study was obtained from the Clinic Director (Appendix C) and Research Director of the said institutions (Appendix B).

3.4 Advertising and Recruitment

Participants were recruited via copies of an advertisement (Appendix G) that were placed in public areas on the DUT campus and that were handed out at community events. Word of mouth recruitment as a form of snowball sampling was also used. Individuals that respond were screened telephonically (Appendix H) to assess whether they would be appropriate as participants in the study. If the telephonic screening was successful, a potential participant was then invited to undergo a physical consultation at the DUT Chiropractic Day Clinic.

Only once participants had read and signed the letter of information and consent (Appendix E) were they included in the study. Participants also underwent a thorough medical history (Appendix I), physical examination (Appendix J), and cervical regional examination (Appendix K) to rule out any potential contraindications that might compromise their participation.

3.5 Sampling

3.5.1 Population and sample size

The population was any person between the ages of 18 and 55, who had manifested non-traumatic neck pain for 4 weeks or more and had not received treatment for their condition within three months previous to their participation. The study thus sampled participants from a wide population within the practical geographical constraints of the greater Durban area. The process of sample determination is discussed in section 3.8.

Suffice it to state here that the ideal sample was determined at 28 per group (experimental and control) and that the total sample thus comprised 56 participants.

3.5.2 Sample characteristics

3.5.2.1 Inclusion criteria

The following inclusion criteria applied:

- Representatives of both genders were included, although an equal proportion of male and female participants was not a requirement.
- All the selected participants were required to read a letter of information and to sign an informed consent letter.
- Participants had to be between the ages of 18 and 55. This age range was established to avoid the need to obtain parental consent for individuals younger than 18 and to exclude potential confounding due to age-related impairments in laterality judgment ability in the elderly (Wallwork et al. 2013).
- Participants had to have experienced neck pain for at least four weeks prior to participation in order to qualify for cases of persistent rather than acute pain.
- Upon examination, patients were included who had at least one restriction in the cervical spine which is an indication for spinal manipulation.

3.5.2.2 Exclusion criteria

The following exclusion criteria applied:

- Applicants were excluded if they had received spinal manipulation therapy for their current episode of neck pain in the previous three months.
- All applicants presenting with contraindications to spinal manipulation were excluded.

- Patients with neck pain of traumatic origin or whiplash-associated disorders were excluded as research has shown that this group does not have impaired laterality judgment (Ravat 2017; Breckenridge et al. 2019).

3.5.3 Group allocation

Participants were randomly allocated to either the intervention or control group by using the ‘hat method’. After the sample size had been achieved, 56 slips of folded paper were placed in an envelope. Half of these (28) had the letter ‘I’ whilst the other half had the letter ‘C’ written on them. A single slip of paper was then drawn out of the hat for each participant by a disinterested third party. If the letter ‘I’ was drawn the person was allocated to the intervention group and if the slip read ‘C’ the participant was allocated to the control group. Only the researcher and the disinterested party were aware of the group allocation. At no point were the participants made aware of their allocation either explicitly or implicitly.

3.6 Procedures and Protocol

- Participants were recruited via advertisement notices (Appendix G) placed around the DUT campus or handed out at community events, and by word of mouth.
- Individuals who responded by calling the number in the advertisement were screened telephonically (Appendix H) to assess whether they would be appropriate for participation in the study.
- If the telephonic screening was successful, the potential participants were then invited to attend a physical consultation at the DUT Chiropractic Day Clinic.
- Only once the participants had been examined and read and signed the letter of information and consent (Appendix E) were they included in the study.
- The participants were subjected to a thorough medical history (Appendix I) and a physical (Appendix J) and cervical regional examination (Appendix K) to rule out any potential contraindications to their participation and to ensure that they met all the inclusion criteria.

- The participants were then randomly allocated to either the control or intervention group by a disinterested party using the ‘hat method’ as detailed above.
- Participants from both groups were then asked to complete both pages of the Central Sensitisation Inventory form.
- The participants were then introduced to the Recognize program and given the opportunity to engage in a 20-second practice round to familiarise themselves with this measurement tool.
- The participants were then asked to perform two rounds of the laterality judgment ability assessment tasks consisting of 20 images each for Hand, Neck and the character ‘R’.
- Laterality judgement accuracy and laterality judgement reaction time for both the right- and left-hand sides were recorded by the researcher.
- The respective interventions and controls (as detailed above) were then applied, and participants were given a 2-minute rest period.
- Participants then repeated each of the laterality judgement tasks and their scores were recorded by the researcher onto the data capture form.
- Following participation, participants from both groups were provided with a voucher for a single free treatment at the DUT Chiropractic Day Clinic.

3.6.1 Interventions

3.6.1.1 Spinal manipulation (SM) experimental group

Participants in the intervention group received cervical spinal manipulation (CSM) to those dysfunctional spinal segments that had been indicated by motion palpation. This was done by the researcher under the supervision of a qualified clinician according to the diversified technique described in Bergmann and Peterson (2011). A high velocity low amplitude (HVLA) thrust was applied at the level of dysfunction and the line of thrust was in accordance with the direction in which the fixation was manifested. All adjustments were done in the supine position (Bergmann and Peterson 2011).

C2-C7 rotation, lateral flexion, and extension restrictions or index/pillar push:

- **Indication:** Limited rotation, lateral flexion or extension of C2-C7
- **Researcher position:** Seated at the head of the table, ipsilateral to the lesion at a 45 – 90º angle to the patient.
- **Contact point:** The anterior-lateral aspect of the index finger.
- **Segmental contact point:** Posterior articular pillar of the superior vertebrae.
- **Indifferent hand:** Supported and cradled the participant's head.
- **Vector:** Posterior to anterior with clockwise or counter-clockwise rotation to induce rotation. Medial to Lateral with superior to inferior to induce lateral flexion.
- **Procedure:** The participant's head was rotated away from the side of dysfunction and adjustive contact was established to the degree of rotation, extension, or lateral flexion depending on the dysfunction being treated.
- **Rotation:** Adjustive contact was established on the superior articular pillar as the patient's head was rotated away and laterally flexed towards the side of contact. Thrust was delivered in clockwise or counter-clockwise direction along the planes for the facet joints.
- **Lateral flexion:** To induce lateral flexion, the head was laterally flexed toward the contact side while keeping rotation to a minimum. Thrust was applied medio-inferiorly.
- **Extension:** Contact was made on the posterior pillar as the involved joint was moved into extension and thrust was applied in an anterior direction.

C0-C1 extension restriction in a jam-jar thrust:

- **Indicated (I):** Loss of extension, unilaterally, and/or hypertonic anterior cervical musculature
- **Participant position :** Supine
- **Researcher position:** At the head of the chiropractic table, 45–90º to the fixation, in a fencer stance
- **Contact point:** The hypothenar aspect of the caudal hand was cupped over the mastoid process and ear, with the fingers pointing somewhere between

the eye and the vertex of the head. In some cases, an index contact was also used.

- **Segmental contact point**: The posterior supra-mastoid groove, just posterior to the ear.
- **Indifferent hand:** A broad contact was used to cradle the head and stabilise the neck.
- **Vector:** posterior to anterior and superior to inferior.
- **Procedure:** The participant's head is slightly rotated away from the point of contact and the cranium was extended through both the contact and indifferent hands. The skin and joint slack are then removed, and an impulse thrust is imparted in order to maximise extension of the C0-C1 joint complex.

3.6.1.2 Control group

Participants allocated to the control group were set up as though cervical spinal manipulation were to be delivered (as indicated by motion palpation), but no thrust was applied. The joint was taken to the point from which the HVLA thrust would be applied (end range of motion), held for a period of 5 seconds, and then returned to neutral position. As some participants might have been familiar with spinal manipulation, this control intervention was not expected to act as a true form of placebo but rather as a control for any potential physiological effects of the set up and tactile contact that occurs with CSM.

3.7 Measurement tool

3.7.1 The Recognize application

This study made use of the commercially available Recognize application (www.noigroup.com) (Moseley 2004). This software has precedent in the literature having been used in several previous studies such as those by (Pedler, Motlagh and Sterling 2013) (Elsig et al. 2014). The program presents users with a series of images of a body part (hand, neck, foot, etc.) and gives them the option to select either right or left.

Recognize also allows original images to be uploaded which can be used for testing of the alphabetical character ‘R’.

Upon completing the series, data to determine the mean accuracy and reaction time were generated. For the purpose of this study, the maximum time per image was set at 4 seconds for a series of 20 images each for the hand, neck, and alphabetical character ‘R’.

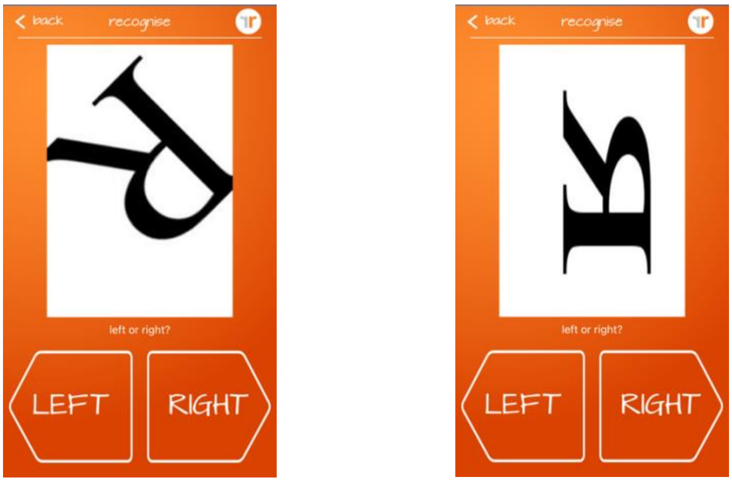

Figure 3.1 and Figure 3.2: The Recognize application’s laterality judgement task for the letter ‘R’

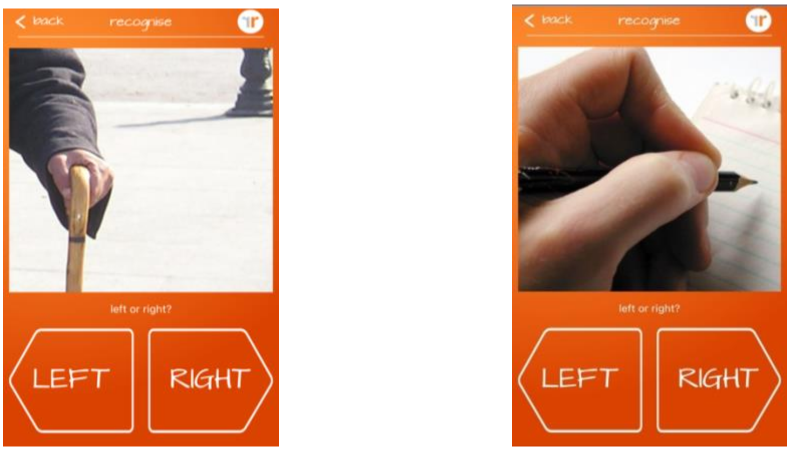

Figure 3.3 and Figure 3.4: The Recognize application’s laterality judgement task for the Hand.

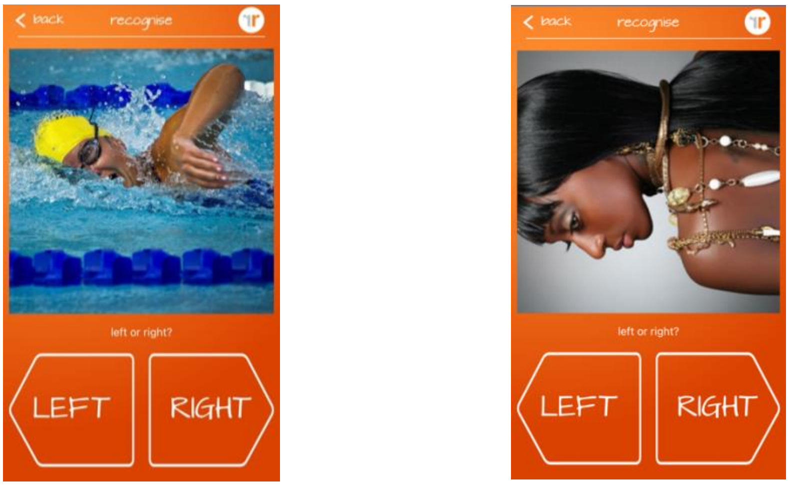

Figure 3.5 and Figure 3.6: The Recognize application's laterality judgement task for the Neck.

3.7.1.1 Measurement tool procedure

The Recognize application was applied as follows:

- The Neck and Hand versions of the Recognize application were downloaded onto a smart phone.
- Twenty (20) images of the upper script letter 'R' were digitally generated and rotated to various degrees. Each of these 20 'R' images were then copied and inverted over the y axis. The full set of 40 images was then uploaded to the Recognize application under the 'My Images' function.
- Each participant was instructed to sit on a chair at a desk. They were verbally instructed to use their dominant hand and to keep their other hand below the desk on their lap. They were also instructed to look only at the screen of the smart phone and to rest the wrist and forearm of their dominant hand in a comfortable position on the desk so that they were able to move their index finger to press the required 'Left' or 'Right' buttons on the smart phone screen.
- Each participant was then introduced to the application.

- For the ‘R’ task the participants were instructed to select ‘right’ if it was a regular ‘R’ (Figure 3.1 above) and to select ‘left’ if it was a reverse or mirror image ‘R’ (Figure 3.2 above).
- With regards to the hand task, participants were instructed to select ‘right’ if they identified a right hand and ‘left’ if they identified a left hand.
- The neck task required participants to select ‘right’ if they identified the neck in the image to be turned, tilted or twisted to the right hand side and to select ‘left’ if they identified the neck in the image to be turned, tilted or twisted to the left hand side.

3.7.2 Central Sensitisation Inventory

The CSI (Appendix M) is known to have a high degree of construct validity and test-retest reliability (Mayer et al. 2012). Part A consists of 25 questions that assess the presence and frequency of symptoms that are known to be related to central sensitisation. Participants were asked to rate the experience of each symptom on a 5-point temporal Likert scale ranging from ‘never’ (0) to ‘always’ (4). The combined score for each of the 25 questions was totalled and a score of more than 40 was deemed to indicate the presence of central sensitisation. In Part B the participants were simply asked to circle any related disorder with which they might have been previously diagnosed.

3.8 Statistical Methodology

Given that addressing the research question involved a comparison of two means, a one-sided two-sample equal variance t-test was chosen for Objective 1, a repeated measures ANOVA test for Objective 2, and Pearson’s correlational analysis for Objective 3 and Objective 4. This was done in consultation with Bio-statistician Tonya Esterhuizen (Personal Communication, 4 November 2019). The null hypothesis of this study was that no difference would exist between the mean improvement for the intervention and control groups. The alternative hypothesis was then that spinal manipulation would lead to a statistically significant ($p<0,05$) improvement in laterality judgement reaction time in participants with persistent neck pain compared to the improvement achieved in the control group. It was also assumed that the internal variance within each group would be equal.

Sample size calculations were informed by the results from previous studies (Baarbe et al. 2016; Elsig et al. 2014; Richter et al. 2010). Of course, at the time the only previous trial to measure the effect of spinal manipulation on mental rotation was that of Baarbe et al. (2016), but the investigation was limited to the allocentric measure of the letter ‘R’. For this reason data from the other two descriptive studies were utilised to generate realistic estimates of population variance for population mean differences and standard deviations for laterality judgements involving body parts.

The calculations suggested a minimum requirement of 28 participants per group. For the primary measurement of laterality judgement reaction time, this group size allowed for a power of 83,736% to reject the null hypothesis of equal means with a population mean difference of 40,59 ms and standard deviation of 57,05 ms. The secondary measurement of laterality judgement accuracy was projected to have a power of 72,383% to reject the null hypothesis with an estimated mean difference of 8 and standard deviation of 13,2. The significance level for both calculations was set at 0,05.

Calculations in terms of Objective 1 were performed using the paired t-test in order to assess whether any differences in mean LJA and LJRT between the intra-group pre- and post-test measurements were statistically significant. This was carried out for each data set for the respective laterality judgement tasks (Hand, Neck, and ‘R’).

The investigation in terms of Objective 2 was undertaken by means of repeated measures ANOVA tests to determine whether the mean improvements in LJA and LJRT for the intervention group were statistically distinct from those of the control group. Again, this was conducted using the data for each respective laterality judgment task.

Objective 3 and Objective 4 required the use of Pearson’s correlational analysis to investigate correlations between egocentric and allocentric measures of laterality judgement performance.

3.9 Ethical Considerations

Ethical approval to conduct this study was obtained from the institution’s Research Ethics Committee prior to the commencement of data capture (Appendix A). Before they could be officially included into the study, each participant had to read and sign the letter of information and consent (Appendix E). The participants were informed that they were free to withdraw from the study at any point without any repercussions.

The four ethical principles of autonomy, justice, beneficence, and non-maleficence were satisfied as follows:

- The autonomy of the participants was respected throughout the research process as ensured by the reading and signing of the letter of information and consent.
- Justice was accounted for on the grounds that no participant was excluded from the study on the basis of race or gender.
- Beneficence was addressed by the high likelihood of direct benefit from cervical spinal manipulation reducing pain, improving joint position sense, and increasing range of motion. Those participants allocated to the control group also benefited as a result of having the opportunity to recoup their voucher for a free treatment at the DUT Chiropractic Day Clinic.
- Non-maleficence was respected by ensuring that no harm was done to the participants as the interventions and measurement tools used are safe.

The coded raw data will stored at the DUT Clinic and destroyed after a period of five years following the conclusion of the study. Hard copy coded data will also be stored at the DUT Chiropractic Day Clinic and destroyed after 5 years. Electronic data will be password protected and stored on a USB at DUT and deleted after a period of five years following the completion of the study. Only the researcher, supervisor, and statistician will have access to the raw data that were elicited. The researcher also undertakes to report the data and discuss the findings in an objective and sensitive manner.

CHAPTER 4
RESULTS

4.1 Introduction

This chapter provides a detailed description of the data and a discussion of the results. Primary data were collected from selected participants who complied with specified inclusion criteria. The following measurement instruments were employed to collect the data:

- Central Sensitisation Inventory (CSI) scores
- Laterality judgement accuracy (LJA)
  LJA ‘R’
  LJA Hand
  LJA Neck
- Laterality judgement reaction time (LJRT)
  LJRT ‘R’
  LJRT Hand
  LJRT Neck

4.2 Data Analysis

4.2.1 Results: Objective 1

This objective was to determine whether either the control or intervention group exhibited improvement in LJRT and/or LJA between the pre- and post-test measurements.

The achievement of this objective required an investigation into whether each group exhibited a statistically significant improvement between the post- and pre-intervention measurements. More specifically, for each measurement category (‘R’, Neck, and Hand accuracy and ‘R’, Neck, and Hand reaction time) an intragroup comparison needed to be made between the mean scores achieved pre- and post-intervention. A paired t-test was used to calculate the significance of any differences in the mean pre- and post-intervention scores for each measurement category as shown in Table 4.1.

Table 4.1: Intragroup paired t-test analysis and input values for the intervention group

	Results of Paired t-test: Intervention Group			
	Pre-test Mean	**Post-test Mean**	**Difference**	**Significance**
'R' Accuracy	90.893	94.018	3.1250	0.046
Neck Accuracy	72.679	80.446	7.7679	0.011
Hand Accuracy	76.339	81.339	5.0000	0.015
'R' Reaction Time	1555.3571	1264.2857	-291.07143	<0.001
Neck Reaction Time	1879.4643	1788.3929	-91.07143	0.065
Hand Reaction Time	1916.9643	1866.0714	-50.89286	0.210

4.2.1.1 Discussion: Objective 1

Table 4.1 shows that, for the intervention group all the parameters indicated a statistically significant change from pre- to post-intervention, except for Neck reaction time and Hand reaction time. In order to be considered statistically significant, the p value should have been less than 0,05. For accuracy, improvement was recorded as an increase can be noted while for reaction time a decrease was considered a positive change.

Table 4.2: Intragroup analysis for the control group

Table 4.2: Intragroup paired t-test analysis and input values for the control group

	Results of Paired t-test: Control Group			
	Pre-test Mean	**Post-test Mean**	**Difference**	**Significance**
‘R’ Accuracy	89.569	90.517	0.9483	0.448
Neck Accuracy	65.259	72.241	6.9828	0.015
Hand Accuracy	78.017	79.828	1.8103	0.336
‘R’ Reaction Time	1582.7586	1385.3448	-197.41379	<0.001
Neck Reaction Time	1998.2759	1898.2759	-100.00000	0.036
Hand Reaction Time	1954.3103	1860.3448	-93.96552	0.024

According to Table 4.2, all the parameters for the control group showed a significant change from pre- to post-intervention, except for ‘R’ and Hand accuracy. The threshold for significance was once again taken to be p< 0,05. For accuracy, increase was considered improvement whilst a decreasing measurement showed improvement in reaction time.

4.2.1.2 Conclusion: Objective 1

The results of the intragroup analyses showed that, for the intervention group, there were statistically significant improvements in all accuracy measures as well as in ‘R’ reaction time. For the control group all reaction time measures showed improvements and so did Neck accuracy, ‘R’ reaction rime, and Hand reaction time. For the control group statistically significant improvements occurred in Neck accuracy, ‘R’ reaction time, and Neck reaction time. This means that any apparent improvements in the absolute scores for other measurement categories in either group were not statistically significant.

4.2.2 Results: Objective 2

This objective was to determine whether the intervention group exhibited a greater mean improvement in LJRT and LJA (for each measure) compared to the control group.

This objective required the use of repeated ANVOA tests to compare changes over time between the two treatment groups. Profile plots were used to visually access the direction and trend of the effect of the intervention and control. Given that the learning effect is a well-established and recognised phenomenon in the literature(Kelly, Murphy and Backhouse 2000; Baarbe et al. 2018), both groups were expected to show improvement over time. The calculations and evaluation thus focused on comparing relative improvements between the two groups.

4.2.2.1 Intergroup analysis for ‘R’ accuracy

Intergroup analysis was performed using repeated ANOVA test measures. A summary of the primary inputs and results for ‘R’ accuracy is presented in Table 4.3 below.

Table 4.3: Inputs and results of repeated ANOVA measures for ‘R’ accuracy

	Repeated ANOVA Measures for ‘R’ Accuracy					
	Pre-test	**Post-test**	**Improvement**	**Inter-group difference**	**Intragroup significance over time**	**Intergroup significance over time**
Intervention Group	90.893	94.018	3.1250	2.1767	0.04	0.265
Control Group	89.569	90.517	0.9483	-2.1767		

There was an overall statistically significant time effect in both treatment groups, but the effect was the same in the groups over time (p=0.040). This means that the intervention group did not produce a significantly different change related to this variable over time. The profile plot in Figure 4.1 below shows that, while there was a slightly higher increase in the 'R' accuracy score of the intervention group over time compared with the control group, this difference was not statistically significant as a high degree of overlap can be detected between the error bars.

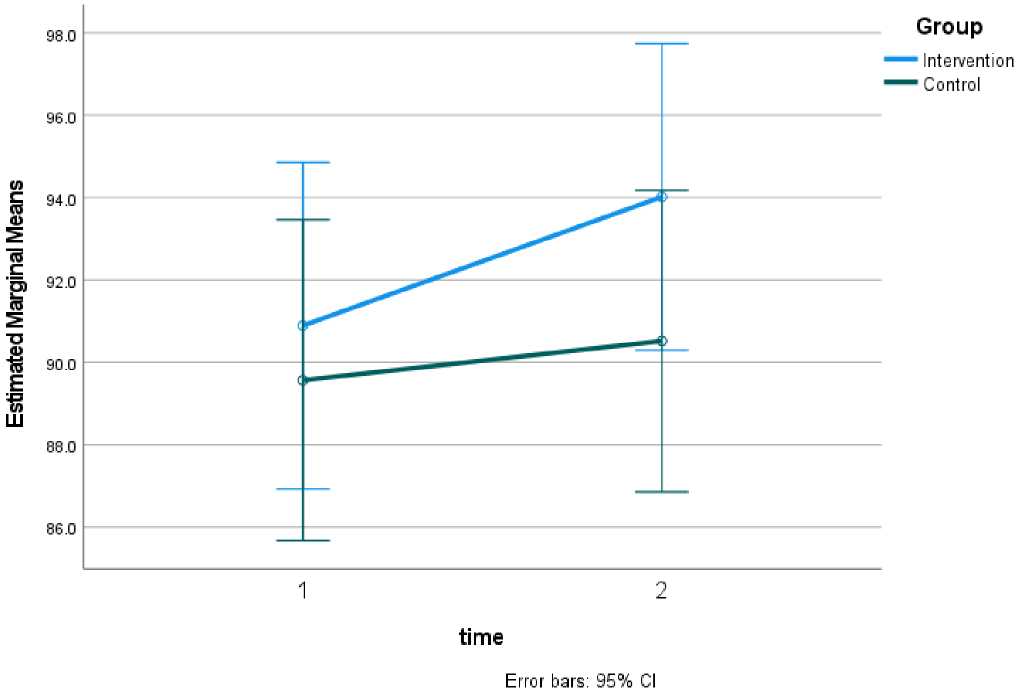

Figure 4.1: Estimated marginal means vs time for 'R' accuracy

4.2.2.2 Intergroup analysis for Neck accuracy

Intergroup analysis was performed using repeated measures of the ANOVA test. A summary of the primary inputs and results for Neck accuracy is presented in Table 4.4 below.

Table 4.4: Inputs and results of repeated ANOVA measures for Neck accuracy

	Repeated ANOVA Measures for Neck Accuracy					
	Pre-test	**Post-test**	**Improvement**	**Inter-group difference**	**Intragroup significance over time**	**Intergroup significance over time**
Intervention Group	72.679	80.446	7.7679	0.7851	<0.001	0.842
Control Group	65.259	72.241	6.9828	-0.7851		

As Table 4.4 indicates, there was again an overall statistically significant time effect in both treatment groups (p=<0.001). However, the effect was the same in both groups over time (p=0.842), which means that the intervention group did not produce a different change related to this variable over time. The profile plot in Figure 4.2 indicates that, while there was a slightly higher increase in the Neck accuracy score over time for the intervention group compared with the control group, this difference was not statistically significant.

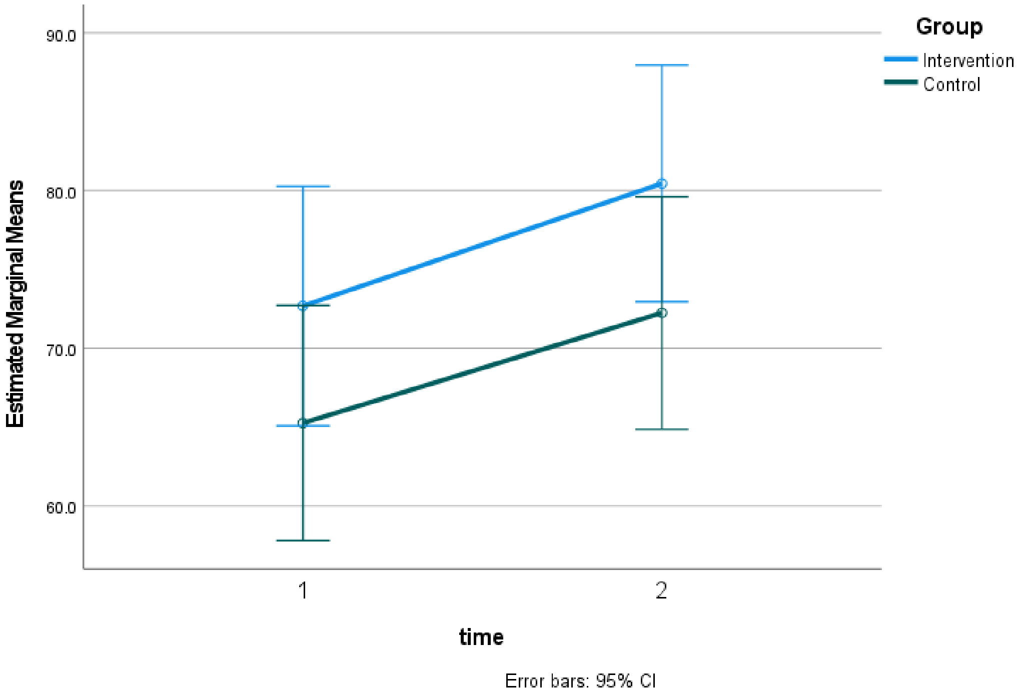

Figure 4.2: Estimated marginal means vs time for Neck accuracy

4.2.2.3 Intergroup analysis for Hand accuracy

Intergroup analysis was performed using repeated ANOVA test measures. A summary of the primary inputs and results for Hand accuracy is presented in Table 4.5 below.

Table 4.5: Inputs and results of repeated ANOVA measures for Hand accuracy

	Repeated ANOVA Measures for Hand Accuracy					
	Pre-test	**Post-test**	**Improvement**	**Intergroup difference**	**Intragroup significance over time**	**Intergroup significance over time**
Intervention Group	76.339	81.339	5.0000	3.1897	0.013	0.236
Control Group	78.017	79.828	1.8103	-3.1897		

There was an overall statistically significant time effect for both treatment groups (p=0.013), but the effect was the same in both groups over time (p=0.236). This means that the intervention group did not produce a different change related to this variable over time. The profile plot in Figure 4.3 shows that the intervention group exhibited a steeper improvement curve compared to the control group; however, the overlap that is indicated by the error bars shows that this was not statistically significant.

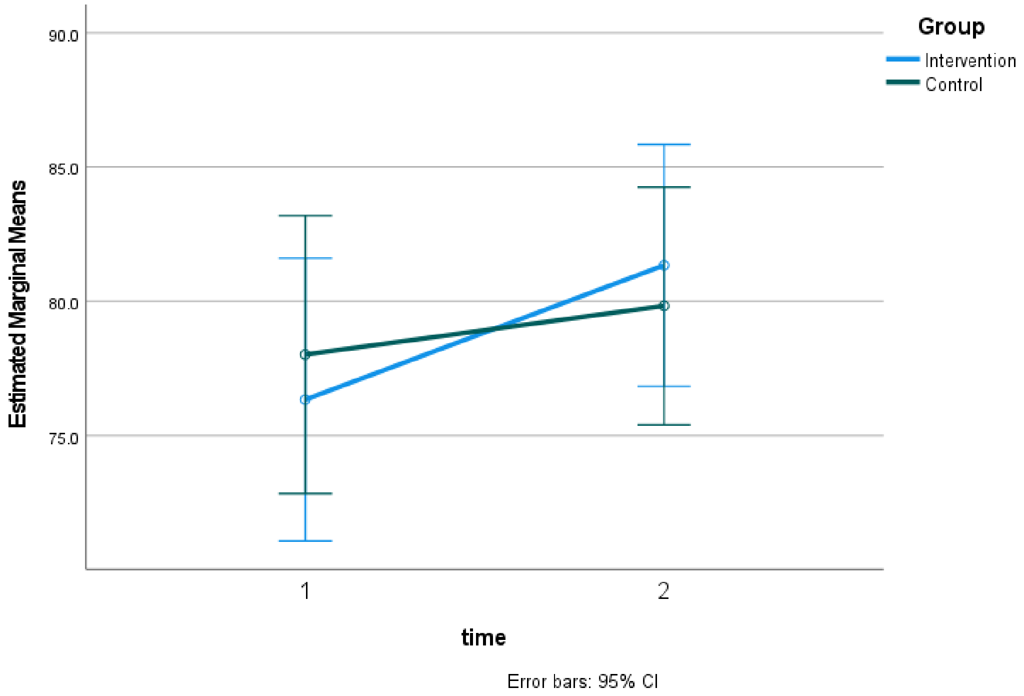

Figure 4.3: Estimated marginal means vs time for Hand accuracy

4.2.2.4 Intergroup analysis for 'R' reaction time

Intergroup analysis was performed using repeated measures of the ANOVA test. A summary of the primary inputs and results for 'R' reaction over time is presented in Table 4.6 below. Generally, improvement in reaction time is considered to occur when time decreases and a greater decrease thus equates to a larger improvement.

Table 4.6: Inputs and results of repeated ANOVA measures for 'R' reaction time

	Repeated ANOVA Measures for 'R' Reaction Time					
	Pre-test	**Post-test**	**Improvement**	**Intergroup difference**	**Intra-group significance over time**	**Intergroup significance over time**
Intervention Group	1555.35	1264.28	-291.07143	-93.65764	<0.001	0.137
Control Group	1582.75	1385.34	-197.41379	93.65764		

As Table 4.6 indicates, there was no statistically significant difference in ‘R’ reaction time over time between the treatment group and the control group (p=0.137), although both groups showed an increase over time (p=<0.001). Figure 4.4 graphically illustrates that, although the intervention group showed a greater improvement in real terms relative to the control group, the considerable degree of error bar overlap shows that this apparent difference was not statistically significant.

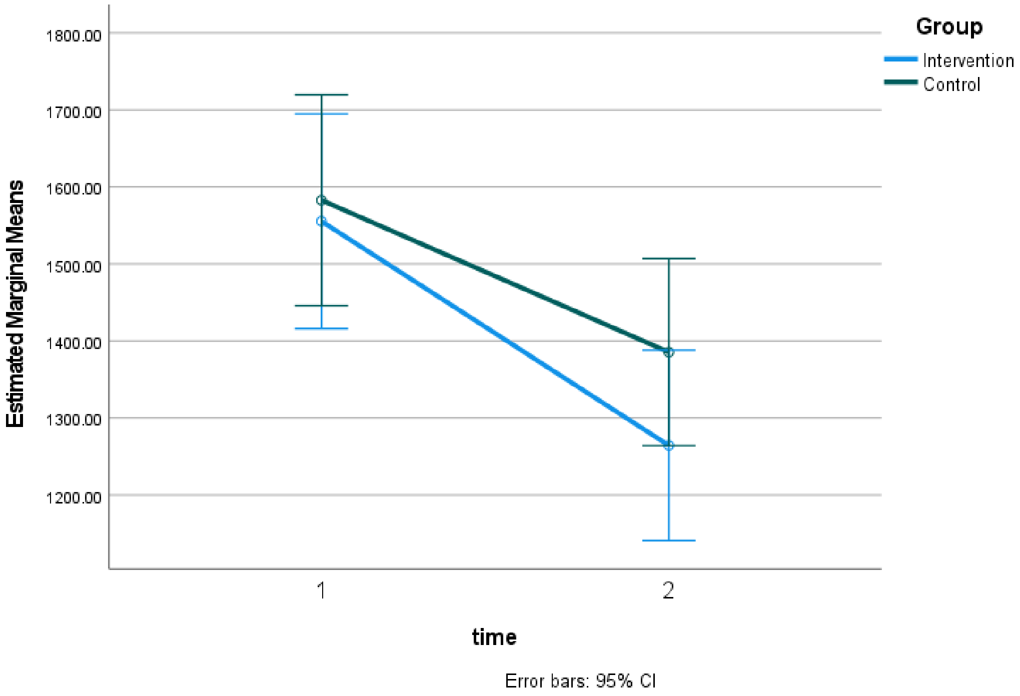

Figure 4.4: Estimated marginal means vs time for ‘R’ reaction time

4.2.2.5 Intergroup analysis for Neck reaction time

Intergroup analysis was performed using repeated measures of the ANOVA test. A summary of the primary inputs and results for Neck reaction time is presented in Table 4.7 below. Improvement in reaction time is considered a decrease in time and thus greater decrease equates to a larger improvement.

Table 4.7: Inputs and results of repeated ANOVA measures for Neck reaction time

	Repeated ANOVA Measures for *Neck Reaction Time*					
	Pre-test	**Post-test**	**Improve-ment**	**Inter-group difference**	**Intragroup significance over time**	**Intergroup significance over time**
Intervention Group	1879.4643	1788.3929	-91.07143	8.92857	0.05	0.892
Control Group	1998.2759	1898.2759	-100.00000	-8.92857		

There was an overall statistically significant time effect in both treatment groups (p=0.005), but the effect was the same for both groups over time (p=0.892). This means that the intervention group did not produce a change related to this variable over time. The slightly steeper gradient of the line representing the control group in Figure 4.5 demonstrates that, in this case, the control group performed marginally better than the intervention group. However, as was indicated by the results of the other measurements, this difference was not statistically significant.

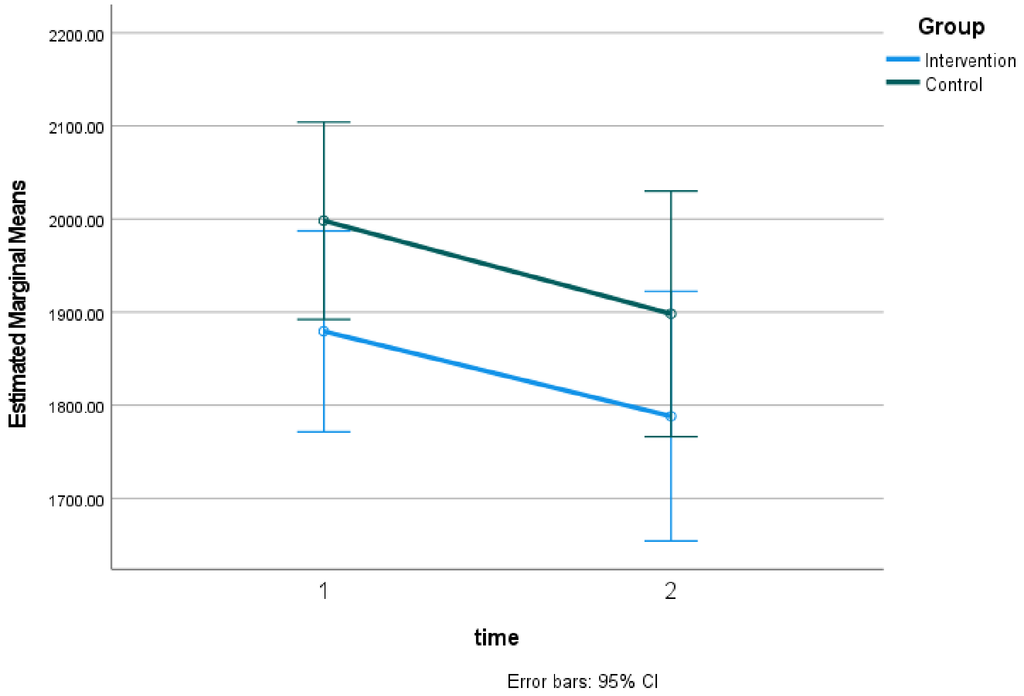

Figure 4.5: Estimated marginal means vs time for ‘R’ reaction time

4.2.2.6 Intergroup analysis for Hand reaction time

Intergroup analysis was performed using repeated ANOVA measures. A summary of the primary inputs and results for Hand reaction time is presented in Table 4.8 below. Improvements in reaction time are associated with a decrease in time, thus a greater decrease equates to a larger improvement.

Table 4.8: Inputs and results of repeated ANOVA measures for Hand reaction time

	Repeated ANOVA Measures for Hand Reaction Time					
	Pre-test	**Post-test**	**Improvement**	**Intergroup difference**	**Intragroup significance over time**	**Intergroup signify-cance over time**
Intervention Group	1916.9643	1866.0714	-50.89286	43.07266	0.012	0.455
Control Group	1954.3103	1860.3448	-93.96552	-43.07266		

There was an overall statistically significant time effect in both treatment groups (p=0.012), but the effect was the same in both groups over time (p=0.445). This means that the intervention group did not produce a different change related to this variable over time. The profile plot in Figure 4.6 shows that the control group appeared to outperform the intervention group, but the error bar overlap illustrates the lack of statistical significance. This means that there was a similar decrease in the Hand reaction time score for the control group over time as in the intervention group.

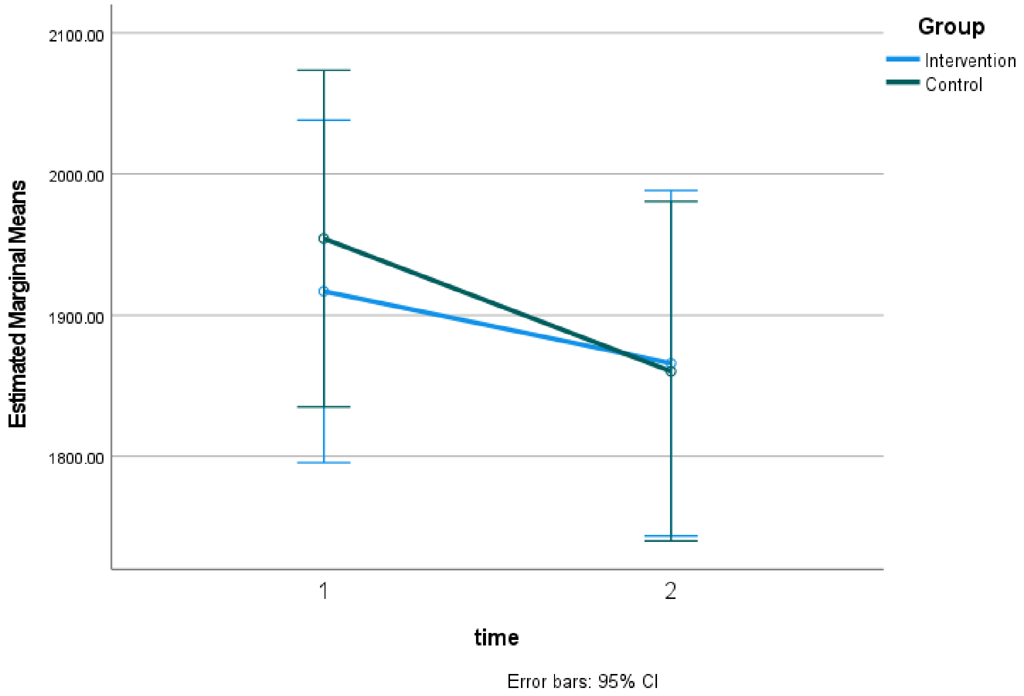

Figure 4.6: Estimated marginal means vs time for Hand reaction time

4.2.2.7 Conclusion: Objective 2

No statistically significant distinctions between the two groups could be found for any measurement category except ‘R’ reaction time. Although both the intervention and control groups improved their performance over time, there were differences in the rates of improvement. In this case the control group actually showed a steeper rate of improvement, however, these differences were insignificant, barring ‘R’ reaction time for the intervention group, which had a 95% confidence interval.

4.2.3 Results: Objective 3

This objective was to determine whether improvements in LJRT and LJA for egocentric laterality judgement tasks (Hand and Neck images) correlated with improvements in LJRT and LJA for allocentric laterality judgment tasks (‘R’).

The achievement of this objective required assessment of the degree of correlation between improvements in egocentric measures of laterality ability (LJA Neck and Hand and LJRT Neck and Hand) and allocentric measures of laterality ability (LJA

‘R’ and LJRT ‘R’). This was done using Pearson’s correlation analysis. Pearson’s analysis generates an r value of between -1 and 1. Perfectly inverse and direct relationships are expressed at the extremes of -1 and 1 respectively. Values of r that are closer to 0 demonstrate the absence of a relationship between the two variables. Generally, an r value of 0.7 is considered to be evidence of a strong correlation. Over and above r values, a significance value can also be calculated to demonstrate the likelihood that the r value is a product of random chance rather than evidence of a true relationship. As with the previous calculations, a p value of less than 0.05 was considered relatively low enough to rule out the possibility that the relationships found within the data were due to chance.

Since there was no statistically significant difference between the effects of the intervention group compared to the control group, these calculations were done using the full sample of 56 participants. This was done under advice from the biostatistician in order to increase the sample size and thus improve the chances of generating statistically significant results (Esterhuizen; Personal Communication, 4 November 2019)

4.2.3.1 Correlation assessments for accuracy scores

Table 4.9 below shows that no evidence of a relationship between ‘R’ accuracy and Neck accuracy improvement was found. This is demonstrated by the fact that the r value was only -0.081. Moreover, the significance level of p=0.550 indicated that any relationship that might exist had a high likelihood of being due to chance. A single participant was no more or less likely to show a high level of pre-test to post-test improvement in Neck accuracy if he/she had already shown a high level of improvement in ‘R’ accuracy.

Table 4.9: Pearson's correlation analysis for 'R' accuracy vs Neck accuracy

	Pearson's Correlational Analysis for 'R' Accuracy vs Neck Accuracy	
	'R' Accuracy	
Neck Accuracy	**-0.081**	Pearson's Correlation
	0.550	Significance
	56	N

The data presented in Table 4.9 reveal that there was also no evidence of relationship between 'R' accuracy and Neck accuracy (r=-0.081, p=0.550). Thus knowing an individual's 'R' accuracy score improvement would have no predicative value to estimate the degree to which the same individual's Neck accuracy score would improve following intervention/control, and vice versa.

Table 4.10: Pearson's correlation analysis for 'R' accuracy vs Hand accuracy

	Pearson's Correlational Analysis for 'R' Accuracy vs Hand Accuracy	
	'R' Accuracy	
Hand Accuracy	**-0.059**	Pearson's Correlation
	0.661	Significance
	56	N

The data presented in Table 4.10 reveal that there was also no evidence of relationship between 'R' accuracy and Hand accuracy (r=-0.059, p=0.661). Thus and individuals Hand accuracy score could not be predicted based upon knowledge of their 'R' accuracy score and visa versa.

4.2.3.2 Correlation assessment of reaction times

Table 4.11 and Table 4.12 below display similar results for reaction time as were found for accuracy. Improvement in 'R' reaction time was not linearly related to Neck reaction time (r=0.041, p=0,760) or to Hand reaction time (r=0.094, p=0.488).

Table 4.11: Pearson’s correlation analysis for ‘R’ reaction time vs Neck reaction time

	Pearson’s Correlational Analysis for ‘R’ Reaction Time vs Neck Reaction Time	
	‘R’ Reaction Time	
Neck Reaction Time	**-0.041**	Pearson Correlation
	0.760	Significance
	56	N

Table 4.12: Pearson’s Correlation analysis for ‘R’ reaction time vs Hand reaction time

	Pearson’s Correlational Analysis for ‘R’ Reaction Time vs Hand Reaction Time	
	‘R’ Reaction Time	
Hand Reaction Time	**-0.094**	Pearson Correlation
	0.488	Significance
	56	N

4.2.3.3 Conclusions: Objective 3

No correlations were found for any of the comparisons of the improvement values between the egocentric and allocentric measurement categories. Although r values for reaction time were higher than those for accuracy, they were still below a reasonable threshold for asserting correlation. Further discussion follows in Chapter 5, but a brief summary is that these results suggest that an individual’s performance in an allocentric laterality judgement task (‘R’ accuracy or ‘R’ reaction time) was not a reliable predictor of that same individual's performance with regards to egocentric laterality judgement tasks (i.e., Neck or Hand accuracy and/or reaction time).

4.2.4 Results: Objective 4

This objective was to determine the extent to which LJA and LJRT performance correlated with Central Sensitisation Inventory scores.

Achieving this objective required assessment to determine if there was a correlation between CSI scores and raw laterality judgement performance and laterality judgement improvement scores over time. To be clear, the first calculation was performed using the raw laterality judgement task scores to determine whether there was a relationship between participants CSI scores and how high they scored. The second calculation utilised the improvements over time in laterality judgment performance to investigate whether there was a relationship between the CSI scores and the participants' ability to learn and improve their laterality judgement performance.

4.2.4.1 Correlation assessment between CSI scores and LJA and LJRT performance

Table 4.13: Pearson's correlational analysis for laterality judgement score vs Central Sensitization Inventory score (N=56)

	Pearson's Correlational Analysis for Laterality Judgement Score vs Central Sensitization Inventory Score (N=56)	
		CSI Score
R Accuracy	Pearson's Correlation	-0.175
	Significance	0.193
Neck Accuracy	Pearson's Correlation	-0.200
	Significance	0.137

Hand Accuracy	Pearson’s Correlation	-0.081
	Significance	0.548
‘R’ Reaction Time	Pearson’s Correlation	0.051
	Significance	0.708
Neck Reaction Time	Pearson’s Correlation	0.130
	Significance	0.336
Hand Reaction Time	Pearson’s Correlation	0.102
	Significance	0.451

Table 4.13 shows that none of the measurement categories displayed evidence of either a direct or indirect proportional relationship to the CSI score. CSI score is not a useful predictor for raw laterality judgement task score with regards to accuracy or reaction time for the letter ‘R’, Neck or Hand.

4.2.4.2 Correlation assessment between CSI scores and LJA and LJRT improvement over time

Table 4.14: Pearson’s correlational analysis for laterality judgement performance improvement vs Central Sensitization Inventory score (N=56)

	Pearson’s Correlational Analysis for Laterality Judgement Performance Improvement vs Central Sensitization Inventory Score (N=56)	
		CSI Score
R Accuracy	Pearson’s Correlation	-0.022
	Significance	0.873
Neck Accuracy	Pearson’s Correlation	0.181
	Significance	0.177
Hand Accuracy	Pearson’s Correlation	-0.058
	Significance	0.666
	Pearson’s Correlation	0.089

‘R’ Reaction Time	Significance	0.508
Neck Reaction Time	Pearson’s Correlation	-0.015
	Significance	0.909
Hand Reaction Time	Pearson’s Correlation	-0.020
	Significance	0.884

According to Table 4.14, there was once again no evidence of correlation between the CSI scores and the degree to which the participants improved in their laterality judgement performance over time.

4.2.4.3 Conclusion: Objective 4

Pearson’s r values ranged from –0.262 to 0.037 and the results were insufficient to suggest the presence of either a positive or negative correlation between CSI scores and improvement in laterality judgement ability over time. Similarly, r values between 0.262 and 0.37 demonstrated a clear lack of correlation between CSI scores and LJA and LJRT pre- or post-intervention scores.

CHAPTER 5
DISCUSSION OF THE RESULTS

5.1 Introduction

This chapter presents an in-depth discussion of the results that were presented in Chapter 4. The discussion is underpinned by findings in existing literature as were outlined in Chapter 2. The results pertaining to each objective will be separately evaluated and overall conclusions will be drawn and observations offered thereafter. Finally, reasonable explanations for the results will presented to explain areas of agreement and disagreement with previous findings and to compare the assumptions of this study with those of others. Particular focus will fall on explaining the differences between the results of the present study with those of the study that was conducted by Kelly et al. (2000). This comparison seems pertinent in light of the similar nature of the two studies and the relative paucity of other similar studies in the literature.

5.2 Objective 1: To determine whether the intervention group exhibited a greater mean improvement in LJRT and LJA (for each measure) compared to the control group

Both groups showed statistically significant pre- and post-intervention improvements for specific variables. The intervention group exhibited these improvements in all measurements related to accuracy but reaction time in the intervention group showed a statistically significant improvement in 'R' reaction time only. The control group also showed significant improvements in all parameters except for 'R' accuracy and Hand accuracy. Although only some measurement categories evidenced improvements that were statistically significant, all measurements showed improvements over time in real terms.

Significant improvements were expected in both groups as a result of the learning effect that is known to take place in trials involving laterality judgement and mental rotation task performance (Kelly, Murphy and Backhouse 2000; Baarbe et al. 2016)

5.3 Objective 2: To determine whether the intervention group exhibited a greater mean improvement in LJRT and LJA (for each measure) compared to the control group

The presence of the learning effect was further demonstrated by the results of the repeated ANOVA tests which showed statistically significant intragroup improvements over time in both groups for all measures. As mentioned above, this learning effect was anticipated and was in line with findings from previous studies(Kelly, Murphy and Backhouse 2000; Baarbe et al. 2016).

In every case the effect on the intervention group was statistically indistinguishable from that of the control group. Although the raw data appeared to show that the intervention group outperformed the control group in ‘R’ accuracy, Hand accuracy and ‘R’ reaction time, these differences were not shown to be statistically significant. This finding is in contrast to what Kelly et al. (2000) found, which was that spinal manipulation improved reaction time for laterality judgements regarding the letter ‘R’ (Kelly, Murphy and Backhouse 2000).

There are several possible explanations for these different results. For instance, the present study measured accuracy in addition to reaction time whilst the trial that Kelly et al. (2000) conducted recorded reaction time only “to make the correct judgement”. It is possible that the participants in the present study were compromising reaction time performance to try and improve and or maintain accuracy. Another possible explanation for the different results is that Kelly et al. (2000) enrolled participants who were all students at the New Zealand Chiropractic School, and thus all of them would have been familiar with the intervention used and they would have been unable to be blinded to the nature of the intervention they received. In contrast, the current study recruited more widely from the general population. Of the 56 participants, 23 were completely ignorant of manipulation and 55 had had no exposure to chiropractic training. Although neither study claimed to have a true placebo but rather a physiological control, it is still possible, if not likely, that the differences in exposure to and familiarity with spinal manipulation may have contributed to disparate outcomes. One possible mechanism for this is that the chiropractic students in the Kelly et al. (2000) study may have had subconsciously moderated their performance to skew the results in favour of the intervention. A second possibility is that the high level of familiarity with the intervention in the same study had a genuinely positive effect on the outcome of the intervention.

Exclusion criteria also differed between the two studies. Whereas the current study included only participants who had not been treated for their current episode of neck pain in the three months prior to the study, the Kelly et al. (2000) study only required that participants should not have had their cervical spine palpated or treated in the six days prior to their study. If this was the case, then it warrants further investigation into whether recent spinal manipulation leads to improved immediate effects of a follow-up dose of this treatment. It may thus be possible that regular chiropractic treatment has a cumulative effect on laterality judgement performance.

A further difference is that Kelly et al. (2000) included participants with subclinical neck pain which they defined as “evidence of upper cervical subluxation, as determined by static and motion palpation procedures”. The present study recruited participants with clinical level neck pain of more than four weeks’ duration. Pointing out this difference is not necessarily to suggest a deficiency in the previous study, but merely that the two studies were interested in measuring slightly different phenomena. The present study sought to investigate the effects of spinal manipulation on the effects of chronic pain with regards to laterality judgment ability. The earlier study was specifically interested in the effects of spinal manipulation on the cervical restrictions with reference to laterality judgement. It is possible that the presence of persistent clinical grade pain had a mitigating influence on the cortical effects of spinal manipulation in the current study.

Kelly et al. (2000) also applied spinal manipulation by means of “a specialized toggle recoil table”, whilst the current study performed spinal manipulation by hand as per the methodology expounded in Chapter 3. It is possible that the different techniques may have produced distinctive effects with regards to the central nervous system.

5.4 Objective 3: To determine whether improvements in LJRT and LJA for egocentric laterality judgement tasks (hand and neck images) were equal to or distinct from improvements in LJRT and LJA for allocentric laterality judgment tasks (‘R’)

There is some discussion in the mental rotation task literature regarding the nature of the neurological mechanisms involved in performing various mental rotation tasks. Specifically, tasks involving body parts are suggested to rely on an egocentric mechanism whilst those pertaining to inanimate objects – such as the letter ‘R’ – would be incorporated into an allocentric mechanism (Dalecki, Hoffmann and Bock 2012). Moreover, a previous study on the effects of spinal manipulation on mental rotation only incorporated an allocentric mechanism test (Kelly, Murphy and Backhouse 2000) In light of this, Objective 3 intended to determine the presence of a correlation between egocentric and allocentric measurements. However, no significant correlation was found across all measurement categories for either the intervention or the control group. This may suggest that changes in laterality judgement performance are to some degree distinct for egocentric and allocentric mechanisms. Individuals who showed the greatest improvement with regards to ‘R’ tasks were no more or less likely to show the same degree of improvement in the Neck or Hand tasks. On the other hand, those whose performance worsened for Neck and Hand tasks were no more or less likely to have worsened performance in the ‘R’ tasks.

Given the general lack of statistical significance with regards to Objective 2, some caution must be exercised when trying to draw out the implications of the lack of correlation for Objective 3. That being said, however, the lack of correlation between improvements in allocentric and egocentric task scores may suggest that the positive effects of spinal manipulation found in the Kelly study regarding allocentric performance improvements ought not to be hastily extrapolated to expect similar improvements in egocentric mechanisms. This lack of correlation can also be tentatively used as a corroborating finding that is in agreement with Dalecki et al. (2012) in that it suggests that egocentric and allocentric laterality judgements may operate according to different mechanisms.

5.5 Objective 4: To determine the extent to which LJA and LJRT performance correlated with Central Sensitisation Inventory scores.

Two Pearson's correlation calculations were performed to achieve this objective. The first compared CSI scores to the improvements in either LJA and LJRT and found no evidence of correlation. Given that the results related to Objective 2 suggest that pre- and post-intervention improvements were likely only due to the learning effect, this then suggests that the extent of central sensitisation has no predictive value for, or relationship with, the learning ability with regards to mental rotation tasks.

The second calculation explored the possibility of a relationship between CSI score values and the raw performance scores for both the pre- and post-intervention measurements for LJA and LJRT. Once again, no linear relationship was found to exist. This suggests that, in so far as CSI score is a true indicator of central sensitisation, laterality judgement tasks are not a reliable predictor of the extent of central sensitisation involved in an individual case of neck pain.

5.6 Conclusions

The overall findings of this study confirmed the null-hypothesis. Cervical spinal manipulation does not lead to an improvement in laterality judgement reaction time and accuracy in participants with persistent neck pain. This finding was confirmed by data that were calculated to statistically compare improvements between the experimental and control groups. Whilst the group that received spinal manipulation did improve their LJA and LJRT performance over time, these improvements were not statistically distinguishable from those of the control group. If anything, when the results of LJRT for the alphabetical character 'R' are considered, they actually suggest that spinal manipulation may have a small limiting role in terms of the benefits of the learning effect. This learning effect, which is extensively described in the literature, appears to have been the only significant factor affecting performance in either group over time.

There are two possible interpretations of this finding for the null hypothesis. The first is that spinal manipulation does not affect laterality judgement ability because it does not affect the cortical functioning of the body schema. Based on this reasoning, it may be concluded that spinal manipulation may not have utility as a treatment targeting the cortical aspects of persistent neck pain.

An alternative interpretation is that, despite longstanding consensus, laterality judgement tasks do not necessarily access the integrity of the body schema, as proposed by (Mibu et al. 2020). If this is the case, then the results of this study are insufficient to draw conclusions about the effects of spinal manipulation on the cortical manifestations of persistent pain because laterality judgement ability is not in fact a reliable measure of the process and extent of cortical maladaptation. Further investigation is thus required to validate or disprove the findings of Mibu et al. (2020) in order to access the legitimacy of this possible line of reasoning.

CHAPTER 6

CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

6.1 Conclusions

This study found in favour of the null hypothesis and suggests that spinal manipulation does not have a significant effect on laterality judgement ability and/or mental rotation tasks in individuals with persistent neck pain.

Although findings pertaining to Objective 1 demonstrated significant improvement in laterality judgement performance in the intervention group following spinal manipulation, similar improvements were demonstrated in the control group as well.

The investigation pertaining to Objective 2 assessed the differences in the extent of improvements between the intervention and control groups. The findings suggest that, although the intervention group appeared to show greater improvements in ‘R’ accuracy, ‘R’ reaction time, and Hand accuracy, these apparent differences could not be adequately shown to be a result of the intervention as opposed to chance variation within the limited sample size for each group. This suggests that the improvements in both groups in terms of Objective 1 were likely due to the learning effect by which participants became increasingly familiar and comfortable with the mental rotations required by the tasks.

To address Objective 3, the possibility of a correlation between changes in allocentric vs egocentric laterality judgement tasks was explored. No correlation was found. Thus an individual participant who improved most significantly with regards to ‘R’ tasks was no more or less likely to show significant improvements in Hand or Neck tasks. This may provide tentative evidence that suggests that allocentric mental rotation task results ought not to be extrapolated to draw conclusions about egocentric performance.

The findings pertaining to Objective 4 revealed no evidence of correlation between CSI scores and either raw laterality judgement task performance or improvement in laterality judgement task performance over time. This suggests that laterality judgement ability ought not to be thought of as a useful indicator of the degree of central sensitisation for individuals with persistent neck pain.

6.2 Clinical Relevance

Based on the findings of this study, spinal manipulation was not demonstrated to provide any cortical benefit to patients who may be experiencing impaired laterality judgement ability due to maladaptation to chronic pain. This is not to say, however, that spinal manipulation does not stand to benefit such patients; rather, it is possible that any such benefits are likely to be limited to the muscular skeletal system rather than the sensory motor functioning of the central nervous system.

6.3 Limitations

This study was impacted by several significant limitations:

- The sample size was restricted to 28 participants per group and this may have reduced the study’s ability to produce statistically significant results. A larger sample size would have increase the study’s validity and reduced the possibility of incorrectly accepting the null hypothesis.
- The study also investigated only the immediate effects of the intervention on laterality judgement performance. As such, it may neither to speak to the medium- or long-term effects of spinal manipulation nor to the possible effects of repeated treatments.
- Although 23 of the 56 participants were completely unfamiliar with manipulation procedures, the others had previously received this intervention. This familiarity with the intervention disallows the claim of a true placebo; rather, it is deemed a physiological control.

6.4 Recommendations

The following recommendations are offered to inform future studies in this field:

- Given the extremely small variation in both accuracy and reaction times, a larger sample size is indicated. This may then improve the likelihood of generating statistically significant results.
- Although this study focused on the immediate effects of spinal manipulation, it may be beneficial to extend the study to involve several treatments and measurements over several weeks. The current study is able to speak only to immediate changes which were no different in the control and intervention groups. However, based on a similar study design there may be differences between the groups over the medium and long term with ongoing treatment.
- The inclusion of a true placebo will increase the scientific validity of the study. This will require excluding any participants who previously experienced spinal manipulation.

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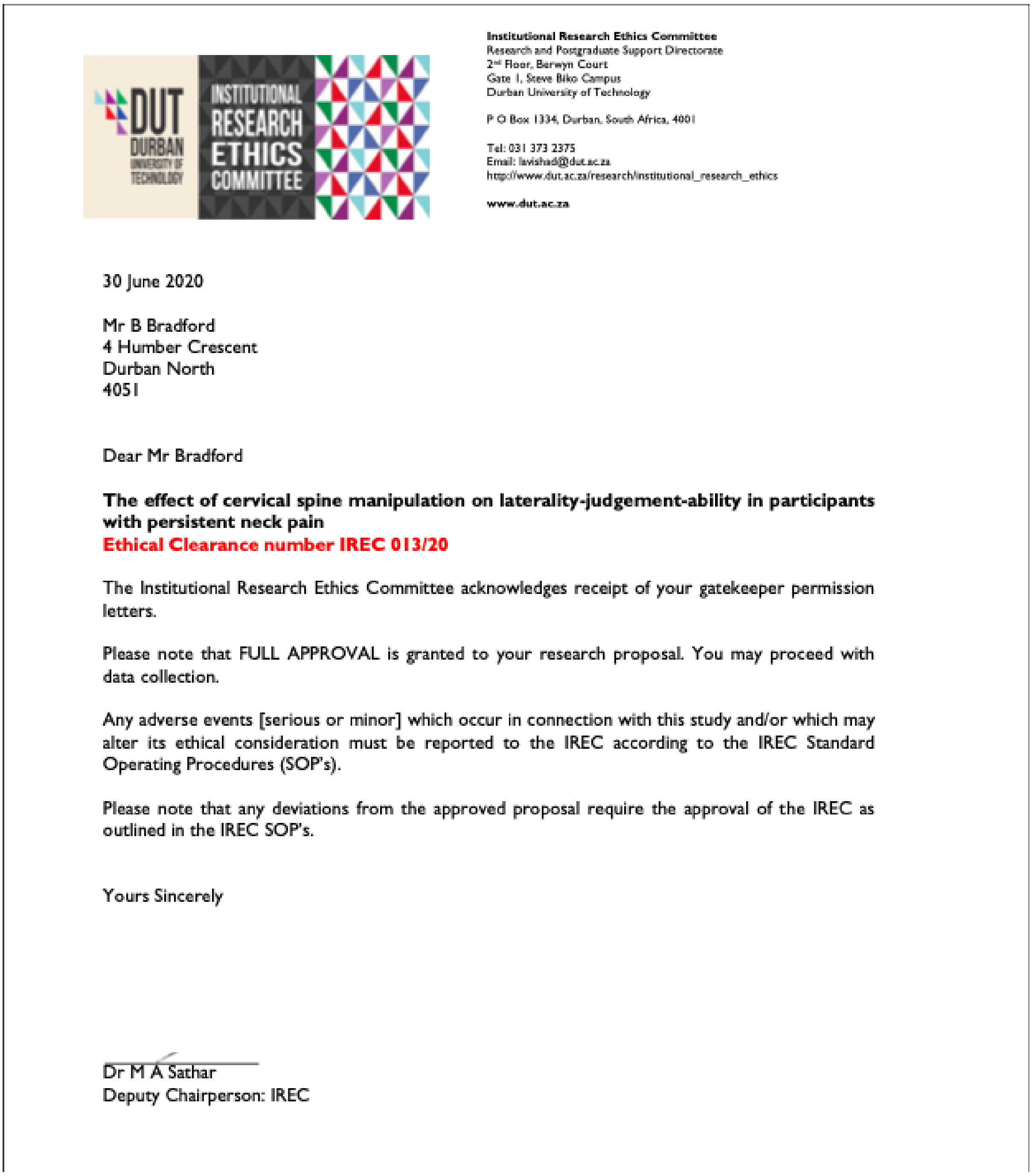
APPENDICES

Appendix A



Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

30 June 2020

Mr B Bradford
4 Humber Crescent
Durban North
4051

Dear Mr Bradford

The effect of cervical spine manipulation on laterality-judgement-ability in participants with persistent neck pain
Ethical Clearance number IREC 013/20

The Institutional Research Ethics Committee acknowledges receipt of your gatekeeper permission letters.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely

Dr M A Sathar
Deputy Chairperson: IREC

Appendix B

Directorate for Research and Postgraduate Support
Durban University of Technology
Tromso Annexe, Steve Biko Campus
P.O. Box 1334, Durban 4000
Tel.: 031-3732576/7
Fax: 031-3732946

9th June 2020
Mr Benjamin Bradford
c/o Department of Chiropractic
Faculty of Health Sciences
Durban University of Technology

Dear Mr Bradford

PERMISSION TO CONDUCT RESEARCH AT THE DUT

Your email correspondence in respect of the above refers. I am pleased to inform you that the Institutional Research and Innovation Committee (IRIC) has granted **Full Permission** for you to conduct your research “The effect of cervical spine manipulation on laterality-judgement-ability in participants with persistent neck pain” at the Durban University of Technology.

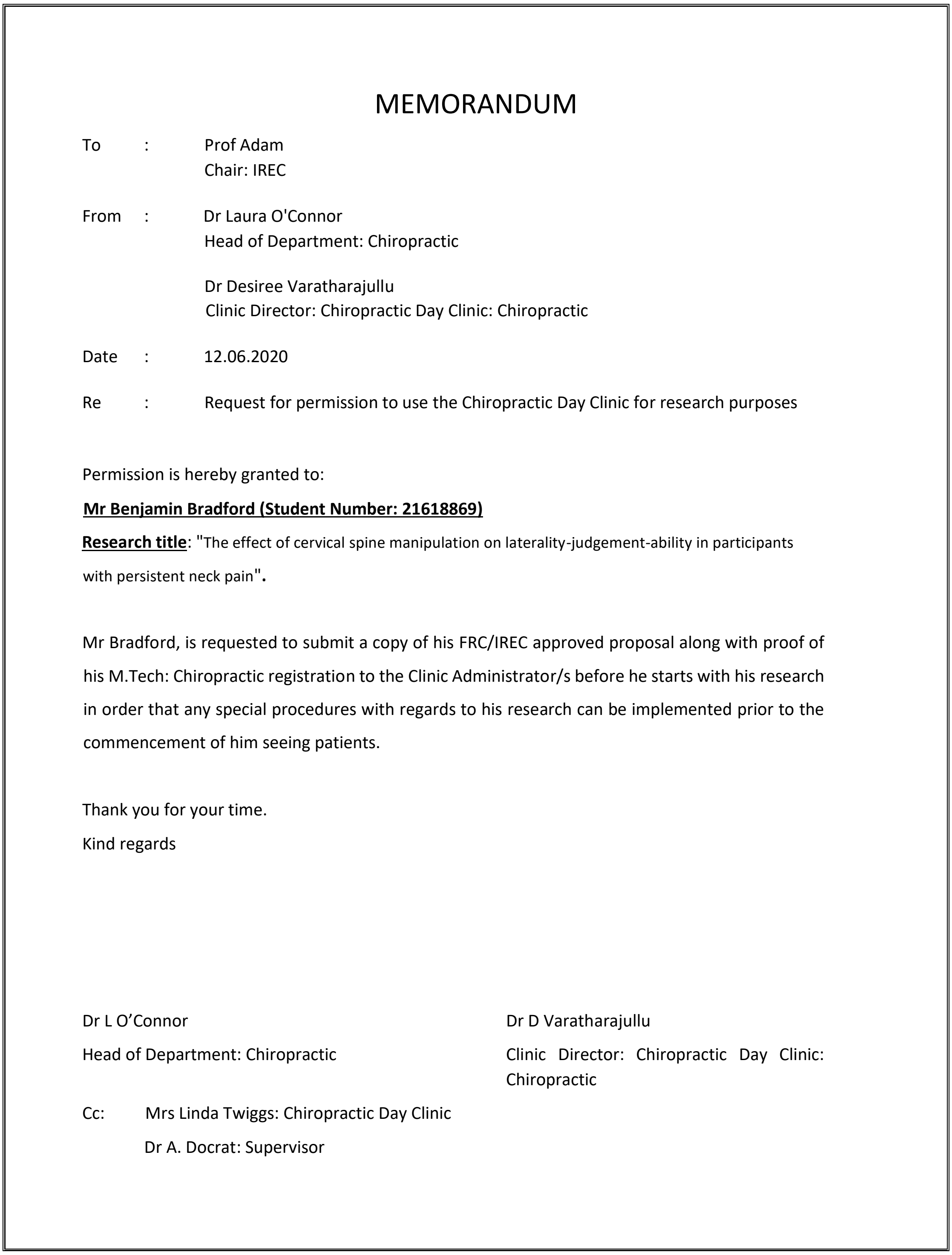
The DUT may impose any other condition it deems appropriate in the circumstances having regard to nature and extent of access to and use of information requested.

We would be grateful if a summary of your key research findings can be submitted to the IRIC on completion of your studies.

Kindest regards.
Yours sincerely

DR LINDA ZIKHONA LINGANISO
DIRECTOR: RESEARCH AND POSTGRADUATE SUPPORT DIRECTORATE

Appendix C



MEMORANDUM

To : Prof Adam
Chair: IREC

From : Dr Laura O'Connor
Head of Department: Chiropractic

Dr Desiree Varatharajullu
Clinic Director: Chiropractic Day Clinic: Chiropractic

Date : 12.06.2020

Re : Request for permission to use the Chiropractic Day Clinic for research purposes

Permission is hereby granted to:

Mr Benjamin Bradford (Student Number: 21618869)

Research title: "The effect of cervical spine manipulation on laterality-judgement-ability in participants with persistent neck pain".

Mr Bradford, is requested to submit a copy of his FRC/IREC approved proposal along with proof of his M.Tech: Chiropractic registration to the Clinic Administrator/s before he starts with his research in order that any special procedures with regards to his research can be implemented prior to the commencement of him seeing patients.

Thank you for your time.
Kind regards

Dr L O'Connor	Dr D Varatharajullu
Head of Department: Chiropractic	Clinic Director: Chiropractic Day Clinic: Chiropractic

Cc: Mrs Linda Twiggs: Chiropractic Day Clinic
Dr A. Docrat: Supervisor

Appendix D

18 March 2020

To Whom It May Concern:

RE: The effect of cervical spine manipulation on laterality-judgement-ability in participants with persistent neck pain

As project manager for the Pan African Clinical Trial Registry (www.pactr.org) database, it is my pleasure to inform you that your application to our registry has been accepted. Your unique identification number for the registry is **PACTR202003801190773**.

Please be advised that you are responsible for updating your trial, or for informing us of changes to your trial.

Please note that it is now a WHO requirement to include, at a minimum, summary results or a link to summary results within the trial registration record. This should be done within 12 months of the study completion date.

Additionally, please provide us with copies of your ethical clearance letters as we must have these on file (via email or post or by uploading online) at your earliest convenience if you have not already done so.

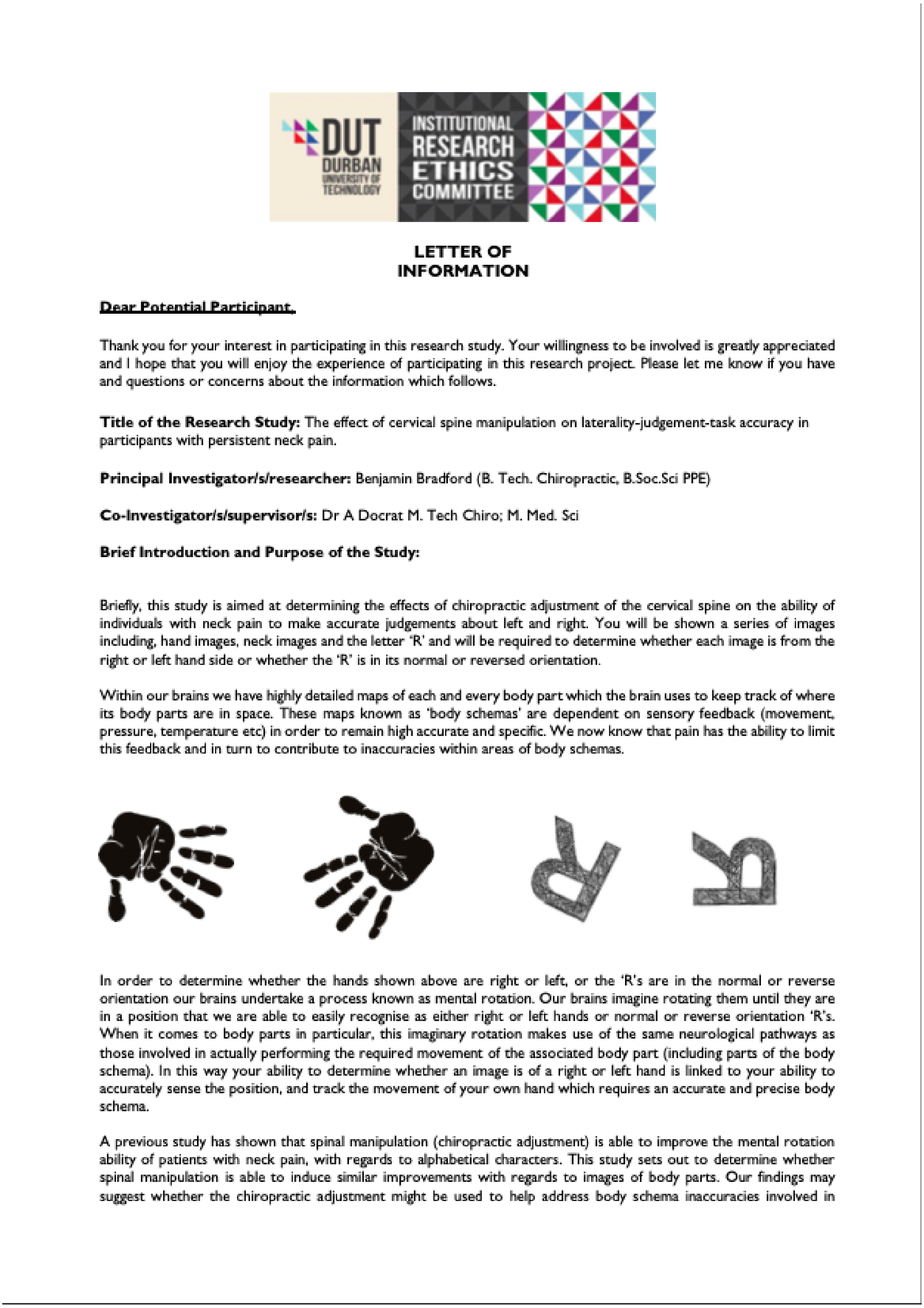
Please do not hesitate to contact us at +27 21 938 0835 or email epienaar@mrc.ac.za should you have any questions.

Yours faithfully,

Elizabeth D Pienaar
www.pactr.org Project Manager
+27 021 938 0835

The South African Medical Research Council
Cochrane South Africa | PO Box 19070, Tygerberg, 7505
Tel: +27 (0)21 938 0438 | Email: cochrane@mrc.co.za | Web: www.southafrica.cochrane.org

Appendix E



DUT DURBAN UNIVERSITY OF TECHNOLOGY INSTITUTIONAL RESEARCH ETHICS COMMITTEE

LETTER OF INFORMATION

Dear Potential Participant,

Thank you for your interest in participating in this research study. Your willingness to be involved is greatly appreciated and I hope that you will enjoy the experience of participating in this research project. Please let me know if you have and questions or concerns about the information which follows.

Title of the Research Study: The effect of cervical spine manipulation on laterality-judgement-task accuracy in participants with persistent neck pain.

Principal Investigator/s/researcher: Benjamin Bradford (B. Tech. Chiropractic, B.Soc.Sci PPE)

Co-Investigator/s/supervisor/s: Dr A Docrat M. Tech Chiro; M. Med. Sci

Brief Introduction and Purpose of the Study:

Briefly, this study is aimed at determining the effects of chiropractic adjustment of the cervical spine on the ability of individuals with neck pain to make accurate judgements about left and right. You will be shown a series of images including, hand images, neck images and the letter 'R' and will be required to determine whether each image is from the right or left hand side or whether the 'R' is in its normal or reversed orientation.

Within our brains we have highly detailed maps of each and every body part which the brain uses to keep track of where its body parts are in space. These maps known as 'body schemas' are dependent on sensory feedback (movement, pressure, temperature etc) in order to remain high accurate and specific. We now know that pain has the ability to limit this feedback and in turn to contribute to inaccuracies within areas of body schemas.

In order to determine whether the hands shown above are right or left, or the 'R's are in the normal or reverse orientation our brains undertake a process known as mental rotation. Our brains imagine rotating them until they are in a position that we are able to easily recognise as either right or left hands or normal or reverse orientation 'R's. When it comes to body parts in particular, this imaginary rotation makes use of the same neurological pathways as those involved in actually performing the required movement of the associated body part (including parts of the body schema). In this way your ability to determine whether an image is of a right or left hand is linked to your ability to accurately sense the position, and track the movement of your own hand which requires an accurate and precise body schema.

A previous study has shown that spinal manipulation (chiropractic adjustment) is able to improve the mental rotation ability of patients with neck pain, with regards to alphabetical characters. This study sets out to determine whether spinal manipulation is able to induce similar improvements with regards to images of body parts. Our findings may suggest whether the chiropractic adjustment might be used to help address body schema inaccuracies involved in persistent pain.

Outline of the Procedures:
In order to participate in this study you will be require to attend an appointment at the Durban University of Technology Chiropractic Clinic. Following a full history and physical exam (to make sure you are a suitable participant), you will be randomly allocated to either a intervention or control group. Your neck will then be accessed for joint fixations which can be treated with chiropractic adjustment. At this point the researcher will explain how to use the application program which measures your laterality judgment accuracy (LJA) and laterality judgement reaction time (LJRT) and you will have time to practice. Once you are familiar with the app a pre-intervention measurement of your LJA and LJRT will be taken. The intervention/control will then be carried out and thereafter a second LJA measurement will be performed. The Data will be recorded and securely filed.

Risks or Discomforts to the Participant: There is a possibility that transient muscle pain may be experienced following cervical spinal manipulation (CSM). This usually resolves spontaneously within 24 hours. You will be accessed for any contraindications to CSM and will be excluded from the study should any be found. Should you wish to withdraw from the study you will not face any repercussions financially, academically or otherwise . Autonomy is ensured when you sign the letter of consent.

Benefits: By participating in this study you will benefit from a free medical history and physical assessment as well as a regional assessment of your cervical spine. You will also benefit from a free chiropractic adjustment of any fixations found within your cervical spine. Should you be allocated to the control group you will be provided with a voucher for a free chiropractic treatment by the researcher at the DUT clinic.

Reason/s why the Participant May Be Withdrawn from the Study: You will be withdrawn from the study in the event of the following:

- You experience any trauma to the neck within 2 weeks of your participation.
- You receive cervical spinal manipulation within 1 week of participation.

There will be no adverse consequences to yourself should you be withdrawn, or choose to withdraw from the study.

Remuneration: No remuneration will be provided for participation in this study.

Costs of the Study: As a participant you will not be required to cover any costs for the study.

Confidentiality: Standard clinical protocol will apply to any and all information given by you. Data will be coded and stored at the DUT Clinic and destroyed after a period of five years following the conclusion of the study. Hard copy data will be stored and coded at the DUT chiropractic clinic and destroyed after 5 years. Electronic data will be password protected and stored on a USB at DUT and deleted after a period of five years following the completion of the study.(Description of the extent to which confidentiality will be maintained and how will this be maintained)

Research-related Injury: Should any adverse reactions occur the researcher in consultation with the supervising clinician will, as necessary, make any required referrals to appropriate specialists.

Persons to Contact in the Event of Any Problems or Queries:

Please contact the researcher (0832292057), my supervisor or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the DVC: Research, Innovation and Engagement Prof S Moyo on 031 373 2577 or moyos@dut.ac.za.

DUT
DURBAN
UNIVERSITY OF
TECHNOLOGY
INSTITUTIONAL
RESEARCH
ETHICS
COMMITTEE

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, (Benjamin Bradford), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: IREC 013/20.

- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.

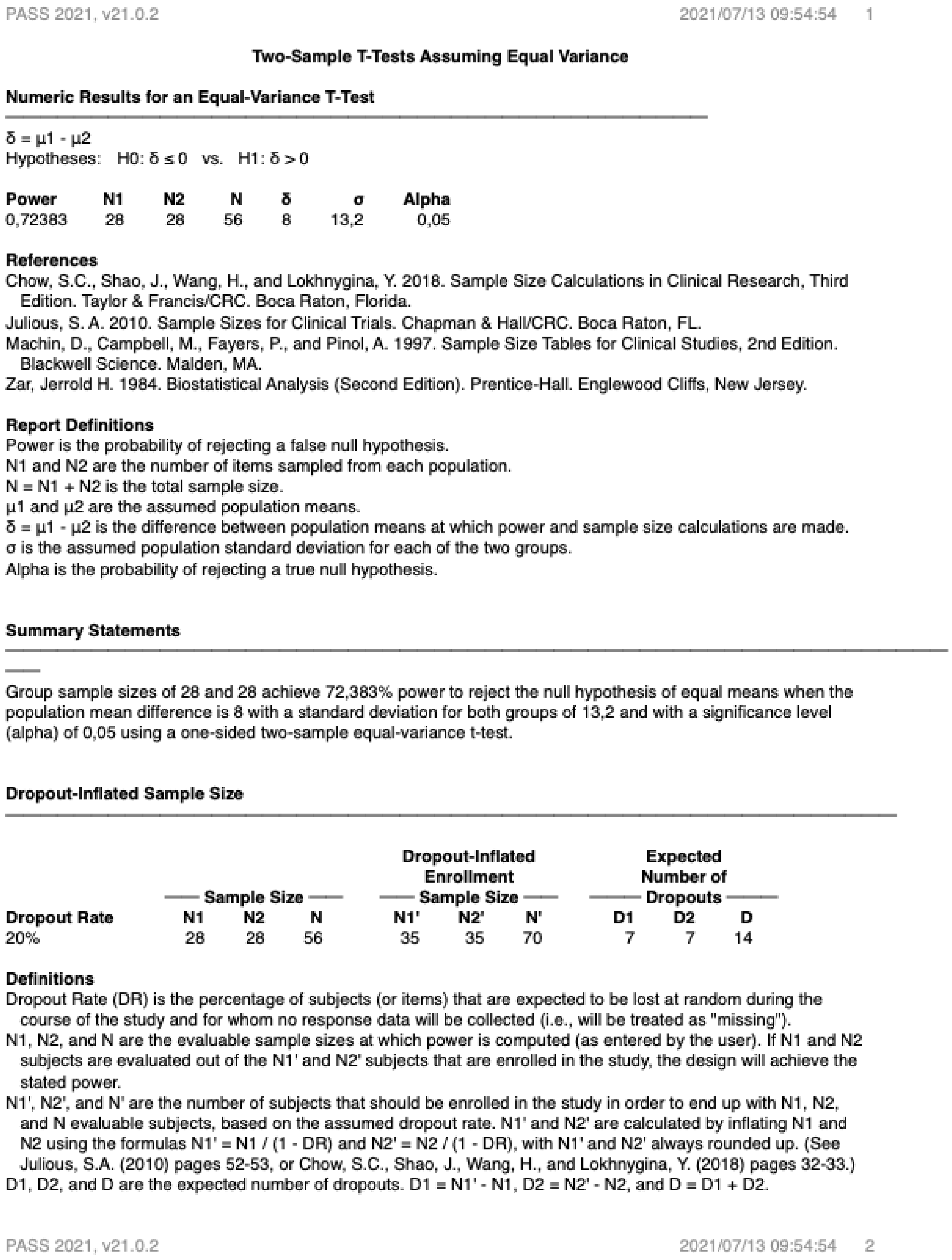
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
-
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
-
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
-
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
-
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

______________________	_____________	_________	______________________
Full Name of Participant	**Date**	**Time**	**Signature**

I, ______________________ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

______________________	_______________	________	____________________________
Witness	**Date**	**Time**	**Signature**

Appendix F



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Two-Sample T-Tests Assuming Equal Variance

Numeric Results for an Equal-Variance T-Test

δ = μ1 - μ2
Hypotheses: H0: δ ≤ 0 vs. H1: δ > 0

Power	N1	N2	N	δ	σ	Alpha
0,72383	28	28	56	8	13,2	0,05

References

Chow, S.C., Shao, J., Wang, H., and Lokhnygina, Y. 2018. Sample Size Calculations in Clinical Research, Third Edition. Taylor & Francis/CRC. Boca Raton, Florida.
Julious, S. A. 2010. Sample Sizes for Clinical Trials. Chapman & Hall/CRC. Boca Raton, FL.
Machin, D., Campbell, M., Fayers, P., and Pinol, A. 1997. Sample Size Tables for Clinical Studies, 2nd Edition. Blackwell Science. Malden, MA.
Zar, Jerrold H. 1984. Biostatistical Analysis (Second Edition). Prentice-Hall. Englewood Cliffs, New Jersey.

Report Definitions

Power is the probability of rejecting a false null hypothesis.
N1 and N2 are the number of items sampled from each population.
N = N1 + N2 is the total sample size.
μ1 and μ2 are the assumed population means.
δ = μ1 - μ2 is the difference between population means at which power and sample size calculations are made.
σ is the assumed population standard deviation for each of the two groups.
Alpha is the probability of rejecting a true null hypothesis.

Summary Statements

Group sample sizes of 28 and 28 achieve 72,383% power to reject the null hypothesis of equal means when the population mean difference is 8 with a standard deviation for both groups of 13,2 and with a significance level (alpha) of 0,05 using a one-sided two-sample equal-variance t-test.

Dropout-Inflated Sample Size

	Sample Size			Dropout-Inflated Enrollment Sample Size			Expected Number of Dropouts		
Dropout Rate	**N1**	**N2**	**N**	**N1'**	**N2'**	**N'**	**D1**	**D2**	**D**
20%	28	28	56	35	35	70	7	7	14

Definitions

Dropout Rate (DR) is the percentage of subjects (or items) that are expected to be lost at random during the course of the study and for whom no response data will be collected (i.e., will be treated as "missing").
N1, N2, and N are the evaluable sample sizes at which power is computed (as entered by the user). If N1 and N2 subjects are evaluated out of the N1' and N2' subjects that are enrolled in the study, the design will achieve the stated power.
N1', N2', and N' are the number of subjects that should be enrolled in the study in order to end up with N1, N2, and N evaluable subjects, based on the assumed dropout rate. N1' and N2' are calculated by inflating N1 and N2 using the formulas N1' = N1 / (1 - DR) and N2' = N2 / (1 - DR), with N1' and N2' always rounded up. (See Julious, S.A. (2010) pages 52-53, or Chow, S.C., Shao, J., Wang, H., and Lokhnygina, Y. (2018) pages 32-33.)
D1, D2, and D are the expected number of dropouts. D1 = N1' - N1, D2 = N2' - N2, and D = D1 + D2.

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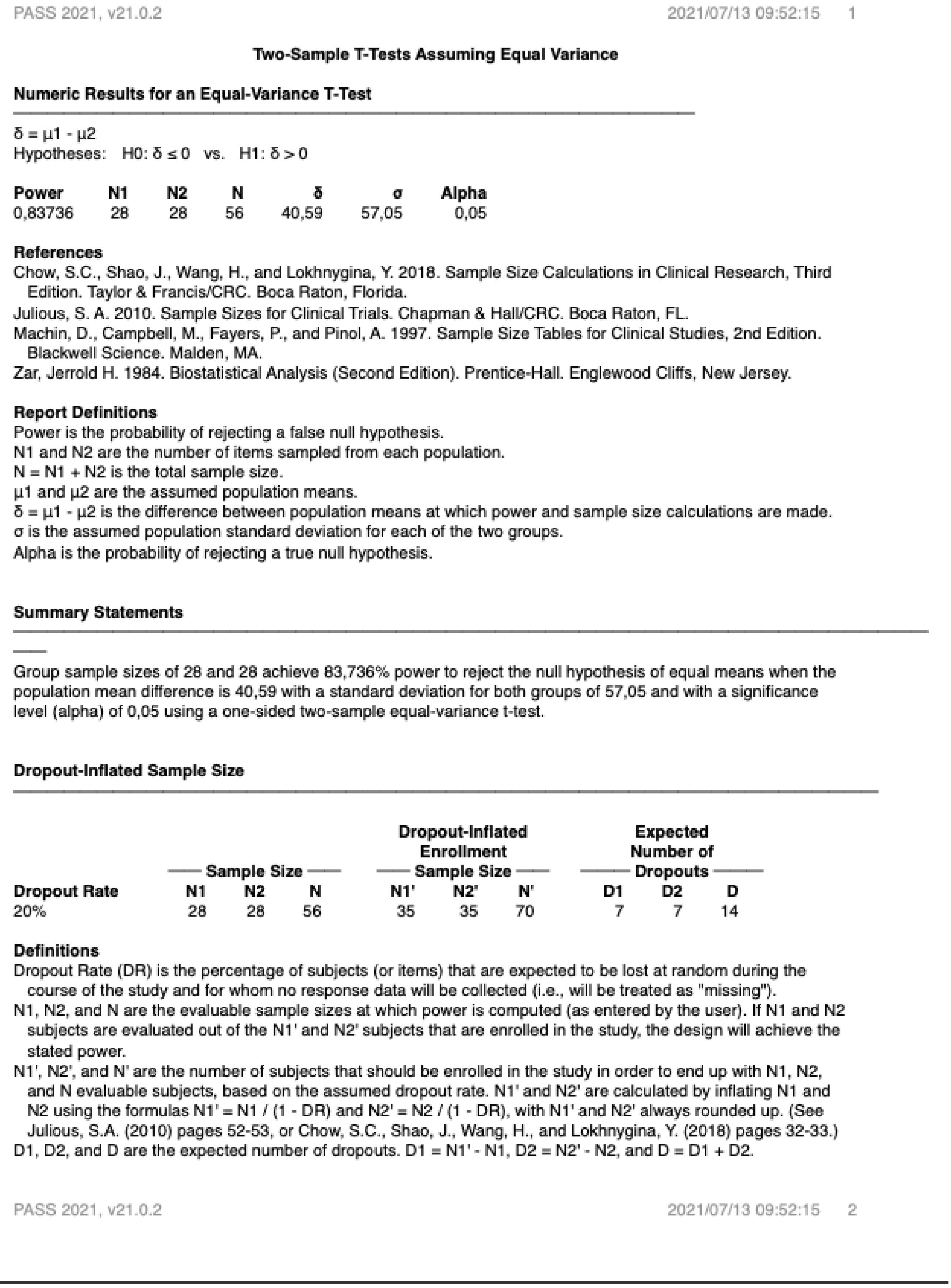

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Two-Sample T-Tests Assuming Equal Variance

Numeric Results for an Equal-Variance T-Test

$\delta = \mu1 - \mu2$
Hypotheses: H0: $\delta \leq 0$ vs. H1: $\delta > 0$

Power	N1	N2	N	δ	σ	Alpha
0,83736	28	28	56	40,59	57,05	0,05

References

Chow, S.C., Shao, J., Wang, H., and Lokhnygina, Y. 2018. Sample Size Calculations in Clinical Research, Third Edition. Taylor & Francis/CRC. Boca Raton, Florida.

Julious, S. A. 2010. Sample Sizes for Clinical Trials. Chapman & Hall/CRC. Boca Raton, FL.

Machin, D., Campbell, M., Fayers, P., and Pinol, A. 1997. Sample Size Tables for Clinical Studies, 2nd Edition. Blackwell Science. Malden, MA.

Zar, Jerrold H. 1984. Biostatistical Analysis (Second Edition). Prentice-Hall. Englewood Cliffs, New Jersey.

Report Definitions

Power is the probability of rejecting a false null hypothesis.
N1 and N2 are the number of items sampled from each population.
N = N1 + N2 is the total sample size.
μ1 and μ2 are the assumed population means.
δ = μ1 - μ2 is the difference between population means at which power and sample size calculations are made.
σ is the assumed population standard deviation for each of the two groups.
Alpha is the probability of rejecting a true null hypothesis.

Summary Statements

Group sample sizes of 28 and 28 achieve 83,736% power to reject the null hypothesis of equal means when the population mean difference is 40,59 with a standard deviation for both groups of 57,05 and with a significance level (alpha) of 0,05 using a one-sided two-sample equal-variance t-test.

Dropout-Inflated Sample Size

	Sample Size			Dropout-Inflated Enrollment Sample Size			Expected Number of Dropouts		
Dropout Rate	**N1**	**N2**	**N**	**N1'**	**N2'**	**N'**	**D1**	**D2**	**D**
20%	28	28	56	35	35	70	7	7	14

Definitions

Dropout Rate (DR) is the percentage of subjects (or items) that are expected to be lost at random during the course of the study and for whom no response data will be collected (i.e., will be treated as "missing").

N1, N2, and N are the evaluable sample sizes at which power is computed (as entered by the user). If N1 and N2 subjects are evaluated out of the N1' and N2' subjects that are enrolled in the study, the design will achieve the stated power.

N1', N2', and N' are the number of subjects that should be enrolled in the study in order to end up with N1, N2, and N evaluable subjects, based on the assumed dropout rate. N1' and N2' are calculated by inflating N1 and N2 using the formulas N1' = N1 / (1 - DR) and N2' = N2 / (1 - DR), with N1' and N2' always rounded up. (See Julious, S.A. (2010) pages 52-53, or Chow, S.C., Shao, J., Wang, H., and Lokhnygina, Y. (2018) pages 32-33.)

D1, D2, and D are the expected number of dropouts. D1 = N1' - N1, D2 = N2' - N2, and D = D1 + D2.

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Appendix G

PAIN IN THE NECK?

Is this a right or left hand Right of Left?

If you have had neck pain for more than 4 weeks and have not had a chiropractic adjustment before then you are invited to participate in a study on the effects of chiropractic treatment on the ability to determine left and right.

If you may be interested contact
Ben Bradford: 0832292057
Or benbchiro@gmail.com

All participants receive a voucher for a free treatment at the DUT Chiropractic Clinic

Appendix H

Question	Yes	No	Comments
1. Are you prepared to answer a few questions over the phone?			
2. Have you received spinal manipulation for your current episode of neck pain within the previous 3 months?			
3. How old are you?			
4. Have you had neck pain for more than 4 weeks?			
5. Did your neck pain result from any trauma or whiplash related incident?			
6. Have you had any surgeries to your neck, shoulder or upper limb?			
7. Have you been adjusted in your neck region in the past week?			

* Potential participants will be considered eligible for the study should they answers correspond to the following:

Question	**Yes**	**No**	**Comments**
1. Are you prepared to answer a few questions over the phone?	X		
Have you received spinal manipulation for your current episode of neck pain within the previous 3 months?		X	
3. How old are you?			Older than 18 and younger than 55 years of age.
4. Have you had neck pain for more than 4 weeks?	X		
5. Did your neck pain result from any trauma or whiplash related incident?		X	
6. Have you had any surgeries to your neck, shoulder or upper limb?		X	
7. Have you been adjusted in your neck region in the past week?		X	

Appendix I

DUT DURBAN UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CHIROPRACTIC

CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient: ____________________ Date: __________

File #: __________ Age: __________

Gender: __________ Occupation: ____________________

Student: ____________________ Signature __________

FOR CLINICIANS USE ONLY:

Initial visit
Clinician: Signature:

Case History:

Examination:
Previous: Current:

X-Ray Studies:
Previous: Current:

Clinical Path. lab:
Previous: Current:

CASE STATUS:

PTT: Signature: Date:

CONDITIONAL:
Reason for Conditional:

Signature: Date:

Conditions met in Visit No: Signed into PTT: Date:

Case Summary signed off: Date:

Student's Case History:

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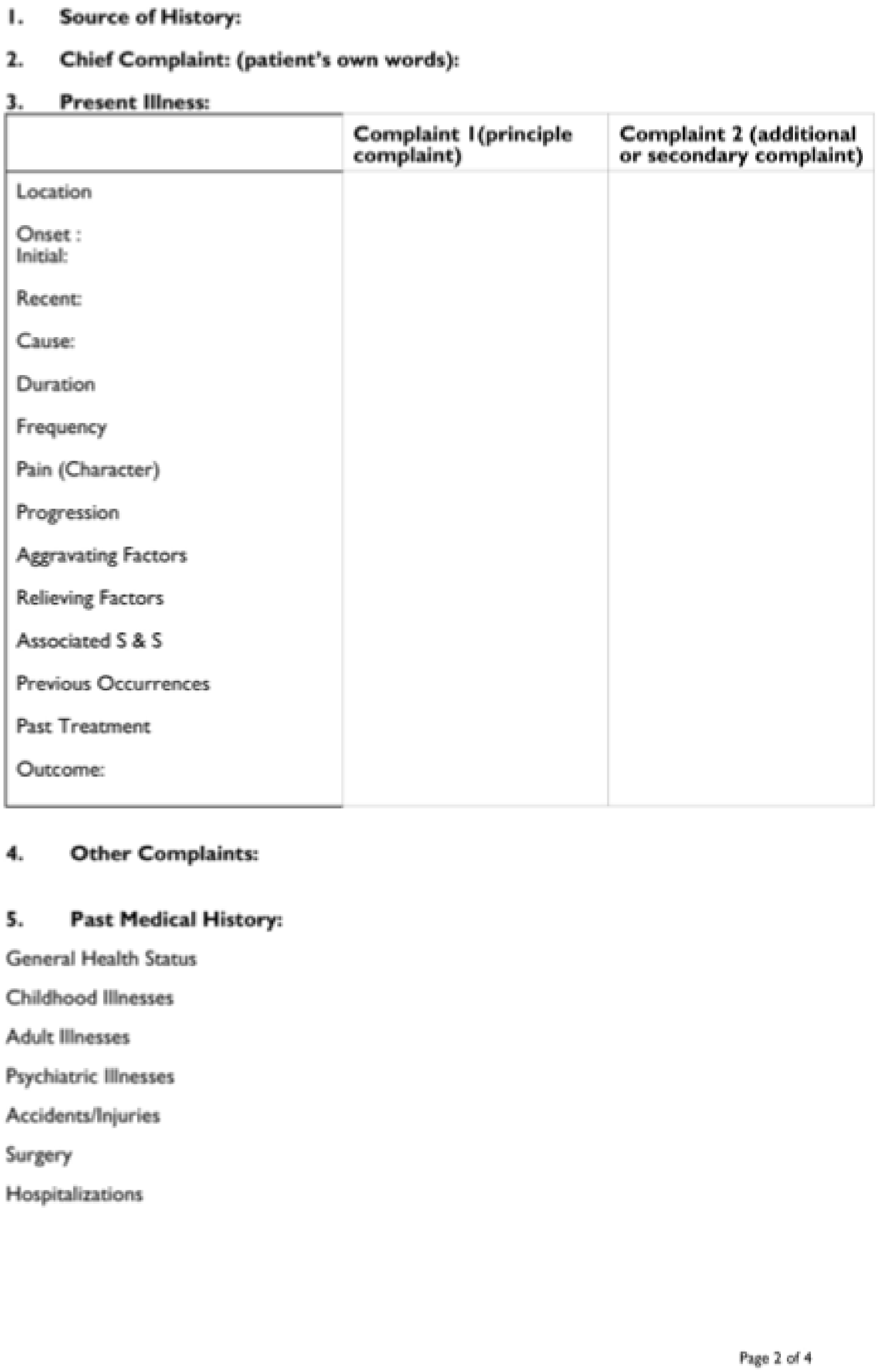


1. **Source of History:**
2. **Chief Complaint: (patient's own words):**
3. **Present Illness:**

	Complaint 1(principle complaint)	**Complaint 2 (additional or secondary complaint)**
Location		
Onset : Initial:		
Recent:		
Cause:		
Duration		
Frequency		
Pain (Character)		
Progression		
Aggravating Factors		
Relieving Factors		
Associated S & S		
Previous Occurrences		
Past Treatment		
Outcome:		

4. **Other Complaints:**

5. **Past Medical History:**

General Health Status

Childhood Illnesses

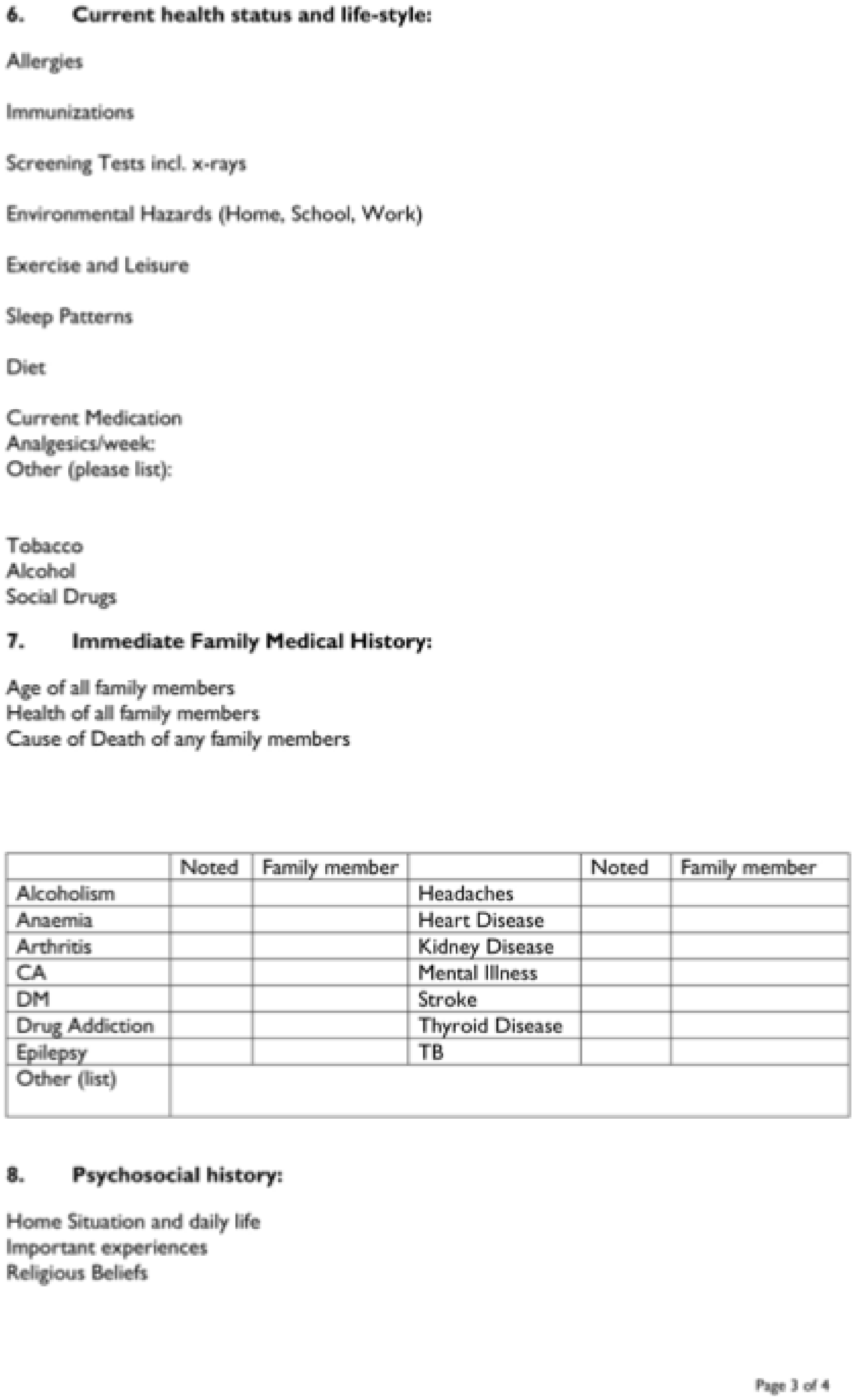
Adult Illnesses

Psychiatric Illnesses

Accidents/Injuries

Surgery

Hospitalizations



6. Current health status and life-style:

Allergies

Immunizations

Screening Tests incl. x-rays

Environmental Hazards (Home, School, Work)

Exercise and Leisure

Sleep Patterns

Diet

Current Medication
Analgesics/week:
Other (please list):

Tobacco
Alcohol
Social Drugs

7. Immediate Family Medical History:

Age of all family members
Health of all family members
Cause of Death of any family members

	Noted	Family member		Noted	Family member
Alcoholism			Headaches		
Anaemia			Heart Disease		
Arthritis			Kidney Disease		
CA			Mental Illness		
DM			Stroke		
Drug Addiction			Thyroid Disease		
Epilepsy			TB		
Other (list)					

8. Psychosocial history:

Home Situation and daily life
Important experiences
Religious Beliefs

9. Review of Systems (please highlight with an asterisk those areas that are a problem for the patient and require further investigation)

General

Skin

Head

Eyes

Ears

Nose/Sinuses

Mouth/Throat

Neck

Breasts

Respiratory

Cardiac

Gastro-intestinal

Urinary

Genital

Vascular

Musculoskeletal

Neurologic

Haematological

Endocrine

Psychiatric

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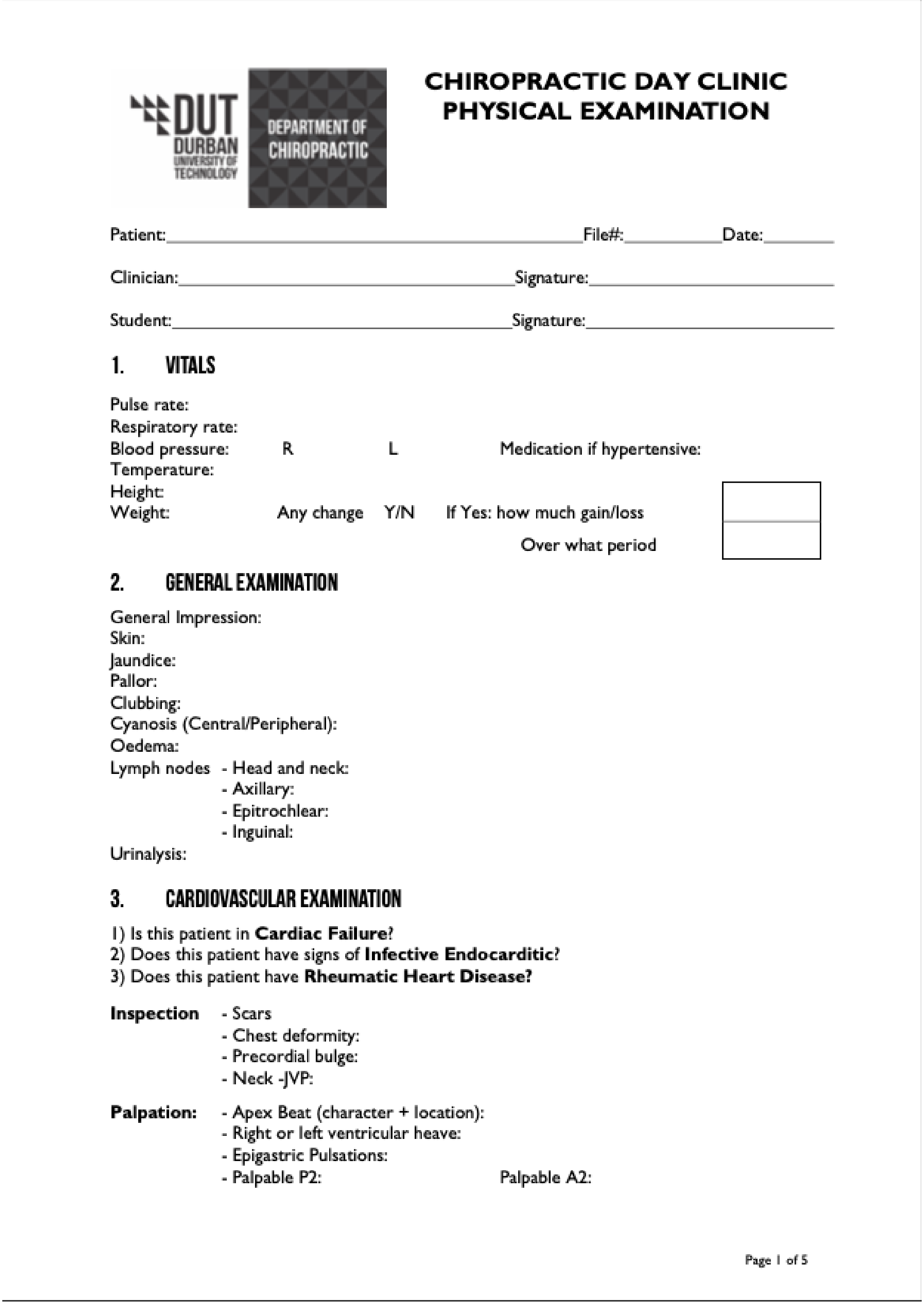
Appendix J



DUT DURBAN UNIVERSITY OF TECHNOLOGY
DEPARTMENT OF CHIROPRACTIC

CHIROPRACTIC DAY CLINIC PHYSICAL EXAMINATION

Patient:____File#:__________Date:________

Clinician:________________________________Signature:_______________________

Student:________________________________Signature:_______________________

1. VITALS

Pulse rate:
Respiratory rate:
Blood pressure: R L Medication if hypertensive:
Temperature:
Height:
Weight: Any change Y/N If Yes: how much gain/loss
Over what period

2. GENERAL EXAMINATION

General Impression:
Skin:
Jaundice:
Pallor:
Clubbing:
Cyanosis (Central/Peripheral):
Oedema:
Lymph nodes - Head and neck:
 - Axillary:
 - Epitrochlear:
 - Inguinal:
Urinalysis:

3. CARDIOVASCULAR EXAMINATION

1) Is this patient in **Cardiac Failure**?
2) Does this patient have signs of **Infective Endocarditic**?
3) Does this patient have **Rheumatic Heart Disease?**

Inspection - Scars
 - Chest deformity:
 - Precordial bulge:
 - Neck -JVP:

Palpation: - Apex Beat (character + location):
 - Right or left ventricular heave:
 - Epigastric Pulsations:
 - Palpable P2: Palpable A2:

Page 1 of 5

Pulses:
- General Impression:
- Radio-femoral delay:
- Carotid:
- Radial:
- Dorsalis pedis:
- Posterior tibial:
- Popliteal:
- Femoral:

Percussion:
- borders of heart

Auscultation:
- heart valves (mitral, aortic, tricuspid, pulmonary)
- Murmurs (timing, systolic/diastolic, site, radiation, grade).

4. RESPIRATORY EXAMINATION

1) Is this patient in **Respiratory Distress**?

Inspection
- Barrel chest:
- Pectus carinatum/cavinatum:
- Left precordial bulge:
- Symmetry of movement:
- Scars:

Palpation
- Tracheal symmetry:
- Tracheal tug:
- Thyroid Gland:
- Symmetry of movement (ant + post)
- Tactile fremitus:

Percussion
- Percussion note:
- Cardiac dullness:
- Liver dullness:

Auscultation
- Normal breath sounds bilateral:
- Adventitious sounds (crackles, wheezes, crepitations)
- Pleural frictional rub:
- Vocal resonance - Whispering pectoriloquy:
- Bronchophony:
- Egophony:

5. ABDOMINAL EXAMINATION

1) Is this patient in **Liver Failure**?

Inspection
- Shape:
- Scars:
- Hernias:

Palpation
- Superficial:
- Deep = Organomegally:
- Masses (intra- or extramural)
- Aorta:

Percussion
- Rebound tenderness:
- Ascites:
- Masses:

Auscultation
- Bowel sounds:
- Arteries (aortic, renal, iliac, femoral, hepatic)

Rectal Examination
- Perianal skin:
- Sphincter tone & S4 Dermatome:
- Obvious masses:
- Prostate:
- Appendix:

6. G.U.T EXAMINATION

External genitalia:
Hernias:
Masses:
Discharges:

7. NEUROLOGICAL EXAMINATION

Gait and Posture
- Abnormalities in gait:
- Walking on heels (L4-L5):
- Walking on toes (S1-S2):
- Romberg's test (Pronator Drift):

Higher Mental Function
- Information and Vocabulary:
- Calculating ability:
- Abstract Thinking:

G.C.S.:
- Eyes:
- Motor:
- Verbal:

EVIDENCE OF HEAD TRAUMA:

Evidence of Meningism:
- Neck mobility and Brudzinski's sign:
- Kernig's sign:

Cranial Nerves:

I Any loss of smell/taste:
Nose examination:

II External examination of eye:
- Visual Acuity:
- Visual fields by confrontation:
- Pupillary light reflexes
  - = Direct:
  - = Consensual:
- Fundoscopy findings:

III Ocular Muscles:
Eye opening strength:

IV Inferior and Medial movement of eye:

V
- a. Sensory
  - - Ophthalmic:
  - - Maxillary:
  - - Mandibular:
- b. Motor
  - - Masseter:
  - - Jaw lateral movement:
- c. Reflexes
  - - Corneal reflex
  - - Jaw jerk

VI Lateral movement of eyes

VII
- a. Motor
  - - Raise eyebrows:
  - - Frown:
  - - Close eyes against resistance:
  - - Show teeth:
  - - Blow out cheeks:
- b. Taste
  - - Anterior two-thirds of tongue:

VIII General Hearing:
Rinne's = L: R:
Weber's lateralisation:
Vestibular function - Nystagmus:
- Romberg's:
- Wallenberg's:
Otoscope examination:

IX & X Gag reflex:
Uvula deviation:
Speech quality:
XI Shoulder lift:
S.C.M. strength:
XII Inspection of tongue (deviation):

Motor System:
a. Power
- Shoulder = Abduction & Adduction:
= Flexion & Extension:
- Elbow = Flexion & Extension:
- Wrist = Flexion & Extension:
- Forearm = Supination & Pronation:
- Fingers = Extension (Interphalangeals & M.C.P's):
- Thumb = Opposition:
- Hip = Flexion & Extension:
= Adduction & Abduction:
- Knee = Flexion & Extension:
- Foot = Dorsiflexion & Plantar flexion:
= Inversion & Eversion:
= Toe (Plantarflexion & Dorsiflexion):

b. Tone - Shoulder:
- Elbow:
- Wrist:
- Lower limb - Int. & Ext. rotation:
- Knee clonus:
- ankle clonus:

c. Reflexes - Biceps:
- Triceps:
- Supinator:
- Knee:
- Ankle:
- Abdominal:
- Plantar:

Sensory System:

a.	Dermatomes	- Light touch: - Crude touch: - Pain: - Temperature: - Two point discrimination:
b.	Joint position sense	- Finger: - Toe:
c.	Vibration:	- Big toe: - Tibial tuberosity: - ASIS: - Interphalangeal Joint: - Sternum:

Cerebellar function:

Obvious signs of cerebellar dysfunction:
= Intention Tremor:
= Nystagmus:
= Truncal Ataxia:
Finger-nose test (Dysmetria):
Rapid alternating movements (Dysdiadochokinesia):
Heel-shin test:
Heel-toe gait:
Reflexes:
Signs of Parkinsons:

8. SPINAL EXAMINATION: (SEE REGIONAL EXAMINATION)

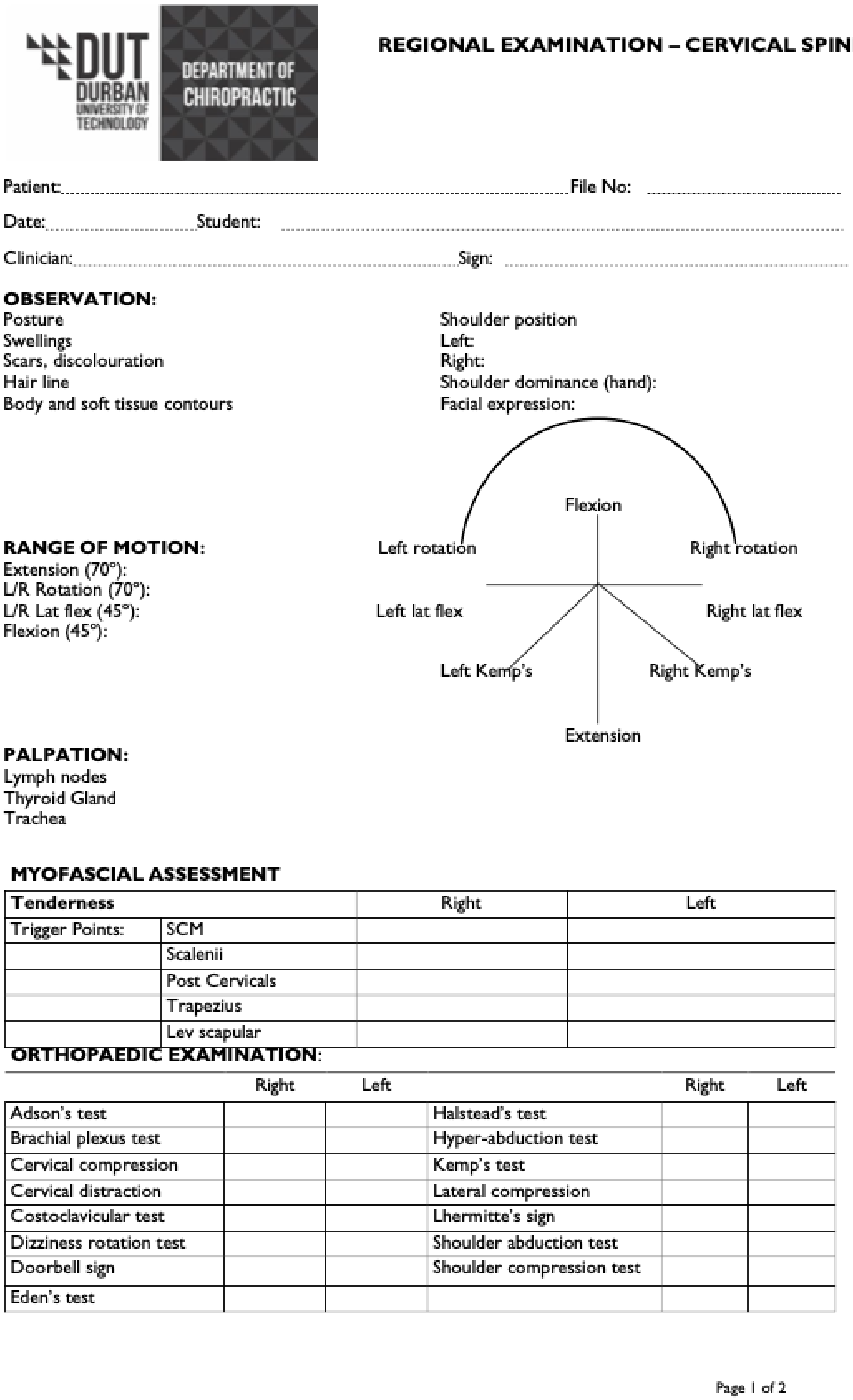
Obvious Abnormalities:
Spinous Percussion:
R.O.M:
Other:

9. BREAST EXAMINATION:

Summon female chaperon.

Inspection	- Hands rested in lap: - Hands pressed on hips: - Arms above head: - Leaning forward:
Palpation	- masses: - tenderness: - axillary tail: - nipple: - regional lymph nodes:

Appendix K



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TECHNOLOGY

DEPARTMENT OF
CHIROPRACTIC

REGIONAL EXAMINATION – CERVICAL SPINE

Patient:.. File No: ....

Date:.................................. Student: ....

Clinician:... Sign: ....

OBSERVATION:

Posture
Swellings
Scars, discolouration
Hair line
Body and soft tissue contours

Shoulder position
Left:
Right:
Shoulder dominance (hand):
Facial expression:

RANGE OF MOTION:

Extension (70°):
L/R Rotation (70°):
L/R Lat flex (45°):
Flexion (45°):

PALPATION:

Lymph nodes
Thyroid Gland
Trachea

MYOFASCIAL ASSESSMENT

Tenderness		Right	Left
Trigger Points:	SCM		
	Scalenii		
	Post Cervicals		
	Trapezius		
	Lev scapular		

ORTHOPAEDIC EXAMINATION:

	Right	Left		Right	Left
Adson's test			Halstead's test		
Brachial plexus test			Hyper-abduction test		
Cervical compression			Kemp's test		
Cervical distraction			Lateral compression		
Costoclavicular test			Lhermitte's sign		
Dizziness rotation test			Shoulder abduction test		
Doorbell sign			Shoulder compression test		
Eden's test					

Page 1 of 2

NEUROLOGICAL EXAMINATION:

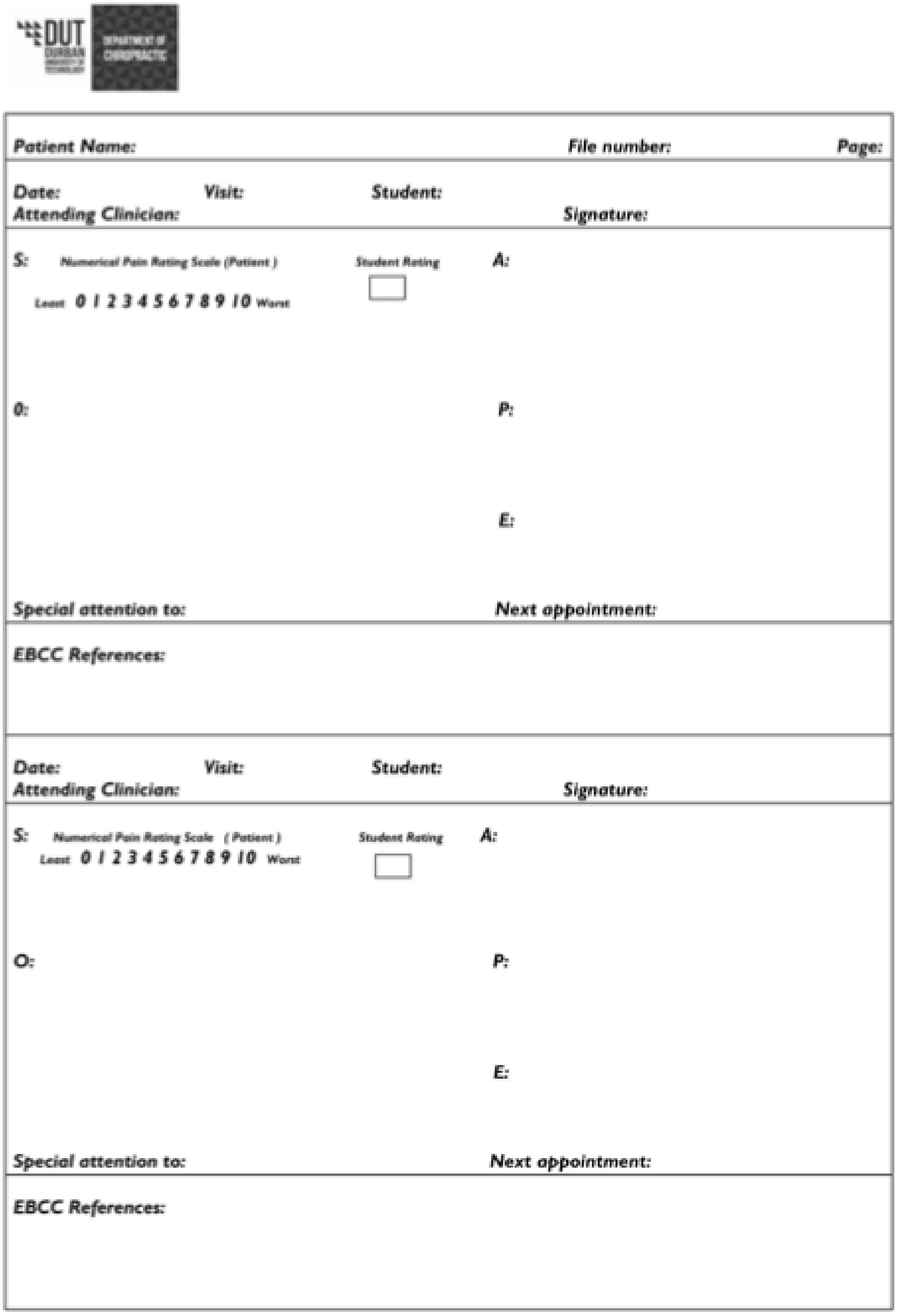
Dermatomes	**Left**	**Right**	**Myotomes**	**Left**	**Right**	**Reflexes**	**Left**	**Right**
C2			C1			C5		
C3			C2			C6		
C4			C3			C7		
C5			C4					
C6			C5					
C7			C6					
C8			C7					
T1			C8					
			T1					
Cerebellar tests:		Left		Right				
Dysdiadochokinesis								

VASCULAR:	**Left**	**Right**		**Left**	**Right**
Blood pressure			Subclavian arts.		
Carotid arts.					

MOTION PALPATION & JOINT PLAY:

Left: Motion Palpation:
Joint Play:
Right: Motion Palpation:
Joint Play:

APPENDIX L



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DEPARTMENT OF CHIROPRACTIC

Patient Name:	**File number:**	**Page:**

Date: **Visit:** **Student:**
Attending Clinician: **Signature:**

S: Numerical Pain Rating Scale (Patient) Student Rating ☐ **A:**
Least 0 1 2 3 4 5 6 7 8 9 10 Worst

O: **P:**

E:

Special attention to: **Next appointment:**

EBCC References:

Date: **Visit:** **Student:**
Attending Clinician: **Signature:**

S: Numerical Pain Rating Scale (Patient) Student Rating ☐ **A:**
Least 0 1 2 3 4 5 6 7 8 9 10 Worst

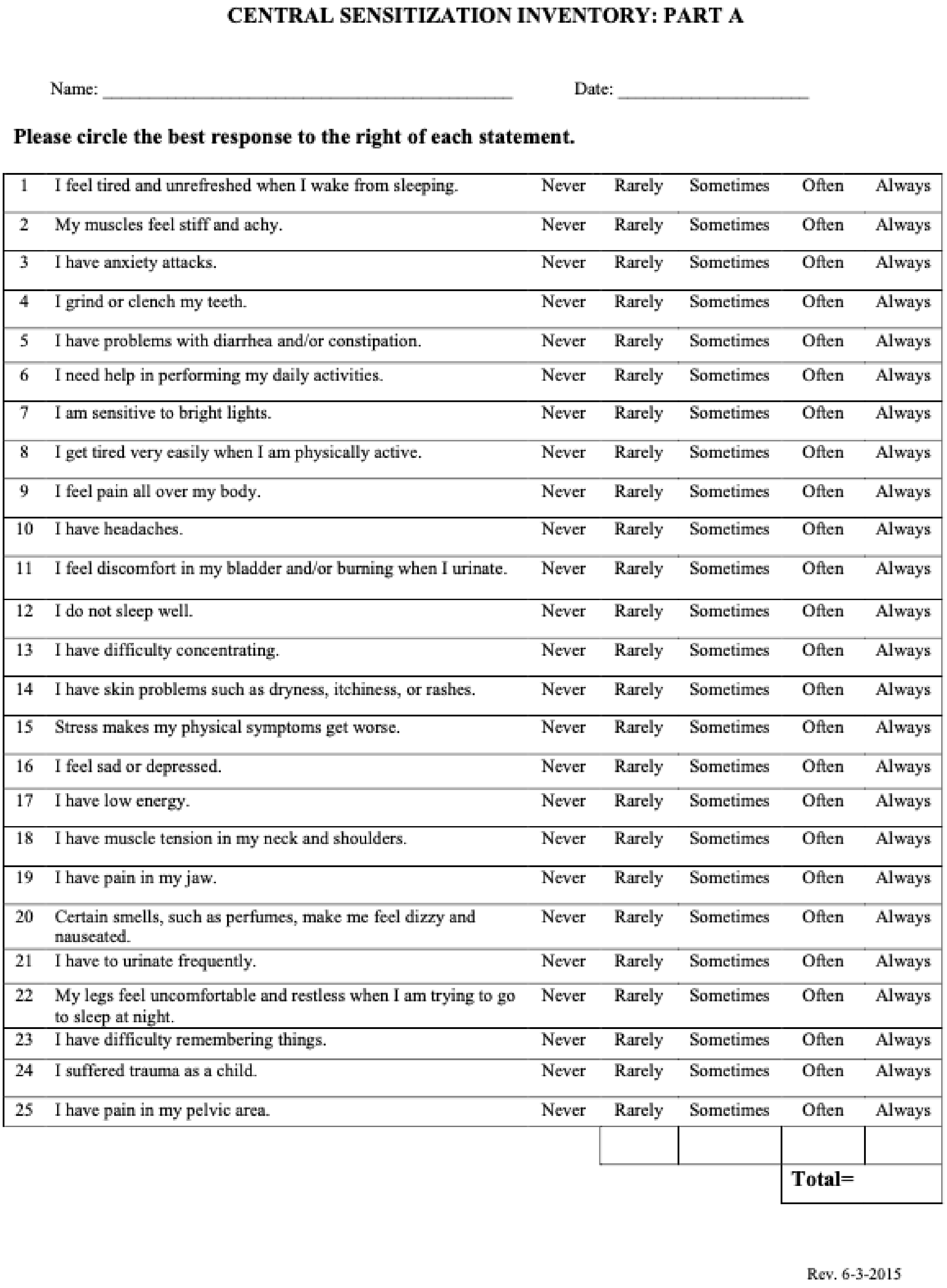
O: **P:**

E:

Special attention to: **Next appointment:**

EBCC References:

Appendix M



CENTRAL SENSITIZATION INVENTORY: PART A

Name: ____ Date: ____________________

Please circle the best response to the right of each statement.

1	I feel tired and unrefreshed when I wake from sleeping.	Never	Rarely	Sometimes	Often	Always
2	My muscles feel stiff and achy.	Never	Rarely	Sometimes	Often	Always
3	I have anxiety attacks.	Never	Rarely	Sometimes	Often	Always
4	I grind or clench my teeth.	Never	Rarely	Sometimes	Often	Always
5	I have problems with diarrhea and/or constipation.	Never	Rarely	Sometimes	Often	Always
6	I need help in performing my daily activities.	Never	Rarely	Sometimes	Often	Always
7	I am sensitive to bright lights.	Never	Rarely	Sometimes	Often	Always
8	I get tired very easily when I am physically active.	Never	Rarely	Sometimes	Often	Always
9	I feel pain all over my body.	Never	Rarely	Sometimes	Often	Always
10	I have headaches.	Never	Rarely	Sometimes	Often	Always
11	I feel discomfort in my bladder and/or burning when I urinate.	Never	Rarely	Sometimes	Often	Always
12	I do not sleep well.	Never	Rarely	Sometimes	Often	Always
13	I have difficulty concentrating.	Never	Rarely	Sometimes	Often	Always
14	I have skin problems such as dryness, itchiness, or rashes.	Never	Rarely	Sometimes	Often	Always
15	Stress makes my physical symptoms get worse.	Never	Rarely	Sometimes	Often	Always
16	I feel sad or depressed.	Never	Rarely	Sometimes	Often	Always
17	I have low energy.	Never	Rarely	Sometimes	Often	Always
18	I have muscle tension in my neck and shoulders.	Never	Rarely	Sometimes	Often	Always
19	I have pain in my jaw.	Never	Rarely	Sometimes	Often	Always
20	Certain smells, such as perfumes, make me feel dizzy and nauseated.	Never	Rarely	Sometimes	Often	Always
21	I have to urinate frequently.	Never	Rarely	Sometimes	Often	Always
22	My legs feel uncomfortable and restless when I am trying to go to sleep at night.	Never	Rarely	Sometimes	Often	Always
23	I have difficulty remembering things.	Never	Rarely	Sometimes	Often	Always
24	I suffered trauma as a child.	Never	Rarely	Sometimes	Often	Always
25	I have pain in my pelvic area.	Never	Rarely	Sometimes	Often	Always
					Total=	

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CENTRAL SENSITIZATION INVENTORY: PART B

Name: ___________________________________

Date: ____________________________________

Have you been diagnosed by a doctor with any of the following disorders?

Please check the box to the right for each diagnosis and write the year of the diagnosis.

		NO	YES	Year Diagnosed
1	Restless Leg Syndrome			
2	Chronic Fatigue Syndrome			
3	Fibromyalgia			
4	Temporomandibular Joint Disorder (TMJ)			
5	Migraine or tension headaches			
6	Irritable Bowel Syndrome			
7	Multiple Chemical Sensitivities			
8	Neck Injury (including whiplash)			
9	Anxiety or Panic Attacks			
10	Depression			

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