The immediate effect of chiropractic cervical spinal manipulative therapy on joint position sense and balance in elderly participants in the eThekwini Municipality

By

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Dissertation submitted in partial compliance with the requirements for the Master's Degree in Technology: Chiropractic Durban University of Technology

I, Robyn Debra Bonsma, do hereby declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate to the contrary)

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DEDICATION

I dedicate this work to the Great Creator and God, my constant pillar of strength, who has helped me through every part of my life and is the essence of knowledge and learning.

To my parents, Emmanuella and Rocco Bonsma; your constant love and support are the reason I was able to get here. This would not have been possible without either of you. Words cannot describe the gratitude I have for you both and the sacrifices you made for me to have this opportunity of education at this level.

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ABSTRACT

Background

The elderly population is growing due to medical advancements. Falls risk is one of the leading causes of death and injury in individuals over the age of 60 years, given that aging causes a degeneration of vestibular, visual and proprioceptive systems, aiding in balance. Chiropractic management has been identified as a strategy which may aid in the improvement of balance. There is a paucity in the literature when it comes to chiropractic treatment and its effect on joint position sense and balance, as well as paucity regarding the elderly population.

Aim

The aim of this study was to determine the immediate effect of cervical spine chiropractic manipulative therapy on joint position sense and sway index, as a part of balance in elderly participants in the eThekwini Municipality, in South Africa.

Method

This was a pre-post study in which 30 healthy participants with a mean age of 71 years of age participated. The elbow joint position sense was measured using a goniometer, and static balance was tested using the Biodex Biosway® portable balance system. The participants reproduced a predetermined angle of flexion of the elbow (blindfolded) pre- and post- intervention. The participants were tested for sway index on the Biodex Biosway® portable balance system with eyes open, pre- and post-intervention. The intervention of this study was a single cervical spine manipulation of the most restricted facet using the diversified technique. The location of the manipulation was not specific to a particular area of the cervical spine but the most restricted segment was adjustment. The joint position sense and balance of the pre- and post-intervention data were compared using statistical software IBM SPSS version 27.

Results

There was a significant improvement of joint position sense (p=0.032) after chiropractic spinal manipulation of the cervical spine; this was shown by the increase in accuracy of joint position sense. There was no significant improvement in static balance (p=0.683) after chiropractic spinal manipulation of the cervical spine. In this study, 76.7% of the participants were female and 23.3% were male and the ethnic distribution was as follows 90% white, 6.7% black and 3.3% Indian.

Conclusion

This study suggests that cervical spinal manipulation may alter sensorimotor functions associated with aspects of balance, such as joint position sense in the elderly, and thus decrease falls. This is due to the improvement in joint position sense post-chiropractic spinal manipulation however, it is unknown if this effect translates to the lower limb. Further studies need to be done to determine the effect of chiropractic manipulation on balance in the elderly as chiropractic spinal manipulation influences aspects of balance in the elderly but it is unclear as to the lasting length of its effects. It is also unclear as to the effect of long-term chiropractic treatment in both balance and falls prevention.

Key Indexing Terms:

Postural balance, proprioception, elderly, spinal manipulation.

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DEFINITIONS

Elderly individuals: are those individuals who are 60 years of age or older, according to the chronological form of the definition by the United Nations (Scherbov and Sanderson 2019).

Joint position sense: is one's ability to sense where a joint is in space and its movement without visual cues (Waugh, Grant and Ross 2010).

Proprioception: is the body's awareness of where it is in space (Dougherty, Anderson and Tsuchitani 2010).

ABBREVIATIONS

AMD	Age-related macular degeneration
AP	Anterior to posterior rotation
BBPBS	Biodex Biosway® portable balance system
CNS	Central nervous system
CSF	Cervical spinal fixations
CSM	Cervical spinal manipulation
LF	Lateral flexion
JPS	Joint position sense
PA	Posterior to anterior rotation
PNS	Peripheral nervous system
PP	Participant position
RP	Researcher’s position
SASSA	South African Social Security Agency
SCP	Segmental contact point
SEP	Somatosensory evoked potential
SMI	Sensory motor integration
SMT	Spinal manipulative therapy
TVP	Transverse process of vertebra

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Each year, 35% of individuals over the age of 65 years succumb to falls (Kenny, Romero-Ortuno and Kumar 2017). This fall incidence rate was found to increase with age (Kenny, Romero-Ortuno and Kumar 2017). Elderly individuals are particularly vulnerable to falls due to the number of risk factors, which they are subjected (Kalula *et al.* 2016). Due to medical advancements, average life expectancy has risen to 85 years and is expected to continue rising, which has resulted in a larger elderly population (Crimmins 2015). Despite the above advancements aging is still accompanied with degeneration and a high susceptibility to injury (Koval *et al.* 2003)

Aging causes structures in the body to become less elastic and weaker (Ferlinc *et al.* 2019). The effect of falls among the elderly being physical, psychological and financial in nature. It is important to note that with aging comes delayed healing due to natural degeneration and fairly often the accompaniment of comorbidities therefore, the consequences related to falls in the elderly tend to be greater than that of younger individuals (Koval *et al.* 2003). Given the consequences of falls among the elderly, this underscores the importance of research in this field (Kim 2016).

Factors that have been identified that play a role in increasing the risk of falls among the elderly include intrinsic (such as impaired vision, dizziness, poly-pharmacy, postural hypotension, decreased proprioception, decreased muscle tone, impaired gait and degenerative disease) and extrinsic (such as uneven ground surface, poor lighting, environmental hazards, stairs lacking a rail and bifocal lenses) factors or a combination of these factors (Lee *et al.* 2022).

The effects of falls among the elderly have a physical, psychological and financial impact (Koval *et al.* 2003). Physical impacts are vast, including fractures, internal haemorrhaging and dislocations (Appeadu and Bordoni 2022). Of falls, 10% result in serious injuries, including fracture of the hip, other fractures, traumatic brain injury, or subdural hematoma (Appeadu and Bordoni 2022). Psychological impacts include disorders such as depression, post-traumatic stress and fear of falling (Kenny, Romero-Ortuno and Kumar 2017). Falling may financially impact the elderly due to medical bills from injury and post-injury care, which is made worse due to a lack of current income due to the individuals being pensioners or retired (Howcroft, Kofman and Lemaire 2013).

An important factor that plays a role in increasing the risk of falls among the elderly are alterations in balance (Osoba *et al.* 2019). There is a marked decrease in proprioception and balance as aging occurs (Alahmari *et al.* 2017). Balance is a process that involves many different aspects to function optimally. It is important that there is optimal communication between three main systems, namely vestibular, visual and nervous systems, all of which work together to maintain a desired bodily position (Osoba *et al.* 2019). Aging has a largely detrimental effect on all three of these systems making balance difficult for the elderly. Common causes of vestibular dysfunction in aging individuals are polyneuropathy and bilateral vestibular hypofunction (Lea and Pothier 2019). Age-related visual impairments include cataracts, presbyopia, decrease in contrast sensitivity, macular degeneration and reduction in visual fields (Salvi, Akhta and Currie 2006; Kahiel *et al.* 2021). The nervous system aspect of balance involves proprioception. Proprioception involves an awareness of one's body's position and movement in space (Henry and Baudry 2019). It refers to mechanoreceptors found in muscles, tendons and joints, which send information to the central nervous system for processing and interpretation (Rowen, Likens and Stergiou 2020). There is a decrease in the release of neurotransmitters; slower peripheral nerve impulse conduction, due to degeneration of the myelin sheath around nerves which contributes to slower reflexes; decreased proprioception, and an overall decrease in balance with aging (Ferlinc *et al.* 2019). Age related changes of the cortex such as a reduction in grey matter, have a negative effect on cortical responsiveness which furthers the negative effects on balance (Eulenburg *et al.* 2017). There is a viscous circle when it comes to falls and the elderly. Falls often are accompanied by injury, which is accompanied by pain and infection management medications, loss of muscle tone, and loss of energy and appetite, which all contribute to further disability and risk of falling (Gould and Fulton 2016). There is also the added risk of falling that comes from fear of falling, which tends to lead to decreased activity and anxiety, resulting in weakness and instability (Ang, Low and How 2020).

In this study, the focus is on joint position sense for proprioception testing. Joint position sense is the body's ability to sense where a specific joint is in space. Due to the modifiable aspect of balance and proprioception, there are mechanisms that have been found to improve balance (Enyinnaya *et al.* 2012).

There are multiple interventions that have been found to improve balance, including interventions such as exercise programmes, tai chi, balance training programmes, environmental adjustments, such as non-slip mats, and spinal manipulative therapy (SMT) (Enyinnaya *et al.* 2012). Spinal manipulative therapy is a modifiable intervention that has been noted to increase neurofeedback as it tends to have an effect on sensorimotor integration.

In a more recent study, the effects of chiropractic care on gait stability of Parkinson sufferers showed that lower-back pain and gait stability improved after 11 weeks of chiropractic adjustments (Chu, Wong and Lee 2021), highlighting that chiropractic care can affect balance. The SMT of dysfunctional cervical segments has also been found to affect central neural function via changes in sensory processing, sensorimotor integration and motor control and plays a significant role in the control of movement and the awareness of ones' body's position in space (Haavik and Murphy 2011). Holt *et al.* (2019) stated that SMT can alter somatosensory processing, sensorimotor integration and motor control. There is value in management strategies that help improve balance, whilst challenging individuals enough to prevent deterioration or weakness caused by lack of activity or dependency, such as with chiropractic care (Kaulmann 2021).

It is clear that the elderly are some of the individuals that need the most help in terms of improving balance (Koval *et al.* 2003). They are however, a vastly understudied population, specifically when it comes to chiropractic care. It has been noted in some of the few studies that have been done on the effects of chiropractic management on the elderly that they receive great benefit from chiropractic treatment (Haavik and Murphy 2011; Hawk and Strunk 2009; Holt *et al.* 2016). It highlights the importance of this study, in focusing on a subject group that will most benefit from the study.

Chiropractic SMT is a non-invasive method of treatment. It is a form of manual therapy or may incorporate a device that helps restore movement and normal functioning, it relieves pressure on joints, decreases inflammation and improves nerve function (Hurwitz 2012; Triano *et al.* 2013). It has been noted to have a positive effect on some risk factors contributing to falls such as postural sway (Osuna and Pérez-Uñate 2021). Studies have shown that chiropractic SMT can alter balance and joint position sense (JPS) which are both intrinsic risk factors for falling (Haavik and Murphy 2011; Hawk and Strunk 2009; Holt *et al.* 2016). Haavik and Murphy (2011) showed that cervical spinal manipulation of dysfunctional segments in individuals with asymptomatic subclinical neck pain can improve their JPS accuracy of the upper limb. Chiropractic adjustments have also been noted to alter sensorimotor integration at a cortical level, which affects balance and proprioception (Lelic *et al.* 2016). Holt *et al.* (2016) revealed that SMT of any dysfunctional joint segment improved both JPS and balance in individuals aged 65 years and older.

1.2 AIM

The aim of this study was to determine the immediate effect of cervical spine chiropractic manipulative therapy on joint position sense and sway index as a part of balance in elderly participants in the eThekwini Municipality.

1.3 OBJECTIVES

1 To compare the balance of elderly participants pre- and post-cervical spine manipulation.

2 To compare joint position sense of elderly participants pre- and post-cervical spine manipulation.

1.4 RATIONALE

The elderly are a growing population who are at high risk of falling due to multiple factors both intrinsic (poor muscle tone, decreased proprioception and impaired gait) and extrinsic (uneven ground, multifocal lenses and poor lighting) (Kenny, Romero-Ortuno and Kumar 2017). Falling can have severely detrimental and long-term effects on the elderly as well as effects on the economy. These detrimental effects include physical, psychological and financial burdens (Koval *et al.* 2003). Medical care post falls is costly whether it be costing the individual privately or the government through state care. Wound care alone due to falls costs the United States more than $25 million per year (Gould and Fulton 2016).

There is clinical evidence of SMT positively affecting some of some intrinsic factors, such as an increase in proprioception and joint position sense (Holt *et al.* 2016). There is a paucity in the literature when it comes to studies involving the effect of SMT on factors contributing to the risk of falling, specifically in developing countries such as South Africa and in the elderly.

Due to South Africa being a third world country, many of the individuals in the lower socioeconomic sector often need to rely on the state for healthcare or alternatively take out personal medical aid, which is a costly exercise (Price 1988). South African state health care has seen a drastic decline in quality (Maphumulo and Bhengu 2019). Third world state health care is seldom sufficient for the elderly, who often need intensive care in hospital and at home, to aid with disabilities that affect the activities of daily living. It is important to investigate mechanisms that increase balance which may help reduce the risk of falls, reducing the need for expensive health care.

Third world countries also tend to have more extrinsic risk factors of falling which highlights the importance of improving intrinsic risk factors to allow for a lower risk of falls. There are significantly more falls in rural community dwellers than in urban dwellers, emphasising the risk involved with individuals' environment (Zhang *et al.* 2019).

This study's value lies in investigating the importance of treatment that could lessen or help to avoid this type of injury and the associated consequences. Although chiropractic care is a relatively expensive form of care, in South Africa there are two chiropractic learning institutions, namely Durban University of Technology and The University of Johannesburg, where there are teaching clinics on the campus which provide affordable chiropractic care to mainly low socio-economic populations.

The effect of SMT on the elderly is vastly understudied. There is research in this field but the paucity allows for this research to have value. A study in New Zealand, on the effects of chiropractic care on balance and joint position sense in the elderly, showed improvements in JPS but balance was tested using the Biodex Biosway® portable balance system on a setting too difficult for the participants to complete. Therefore, the data collected did not show an accurate account of the effect of SMT on balance and rather showed either completion or failure of the test (Haavik and Murphy 2011). This study tested static balance on the Biodex Biosway® portable balance system which is an easier test to complete. It will add to the available literature by providing more information on the effect of SMT on balance.

1.5 CONCLUSION

This chapter highlighted the importance of this study, the aim, objectives and the gap in the literature surrounding balance and the elderly and SMT. It gave an overview of the value this study holds and indicated the content of the chapters that follow.

1.6 STRUCTURE OF DISSERTATION

Chapter 1: A brief overview of the study and the flow of the study.

Chapter 2: Presents the current literature available on this topic and critically analyses it.

Chapter 3: This involves where the study design, location, population, procedure and ethical considerations will be discussed.

Chapter 4: A presentation of the results of the study are outlined.

Chapter 5: This chapter analyses and discusses the results of this study, how the relate to the aims and objectives as well and drawing connections between the results and the literature around this topic.

Chapter 6: This involves the conclusions that have been drawn, and recommendations based on the research outcomes found will be presented, thereby concluding the research project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents the current literature pertaining to this study and focuses on the anatomy of the cervical spine; the central nervous system (CNS); its connection to the peripheral nervous system (PNS), and the function of the PNS. It explains the PNS connection with the innervation of muscles and joints. The chapter elaborates on balance and joint position sense (JPS), what they entail and how they function in the human body. The study investigates the balance and falls among the elderly and how they affect the individual, as well as the economy. Lastly, it explores cervical fixations, cervical spinal manipulation (CSM) and their effect on both balance and JPS. The search engines used for this chapter included but were not limited to Google Scholar, Pubmed and DUT summons, various online and print textbooks.

2.2 ANATOMY, BIOMECHANICS AND NEUROLOGY OF THE CERVICAL SPINE

The cervical spine is typically the most mobile part of the spine; it consists of seven vertebrae. A lordotic curve is a C-shaped curve with the concavity facing posterior. The cervical spine has a natural lordotic curve between the skull and the thoracic spine (Moore, Dalley and Agur 2014: 982–984). Among other things, the purpose of the curve is to allow for mastication, breathing, act as a shock absorber and carry the weight of the head by keeping it aligned over the body (Geo *et al.* 2018). Factors that can affect the normal lordotic curve include, but are not isolated to, decreased cervical stability, joint degeneration, poor posture, fractures and birth defects (Gao *et al.* 2018).

The natural curvature of the spine is directly related to nervous system functioning, as any abnormal structure can cause pressure on the nerves or spinal cord and affect their function. Therefore, the curvature of the spine influences the overall health of individuals. Correct biomechanical function can be compromised by an abnormal lordotic curvature of the cervical spine (Gatterman 2005). The vertebrae of the cervical region serve to protect the cervical section of the spinal cord (Yow *et al.* 2021).

The cervical spine is unique in that it is highly mobile, with the most mobile segments being C1/C2; these two vertebrae are unique in comparison to the rest of the cervical spine as they do not have transverse processes and C2 has a bony prominence called an odontoid process (Moore, Dalley and Agur 2014: 982–985). The cervical vertebrae C3 to C7 have very short transverse processes in comparison to the thoracic and lumbar vertebrae in the spine; the spinous process in the cervical spine is bifid, unlike the rest of the spine (Moore, Dalley and Agur 2014: 982–985). They also differ from other spinal vertebrae due to their transverse foramina through which the vertebral artery runs to supply blood to the brain (Agur and Dalley 2018). The anatomy of the cervical spine can be seen in **Figure 2.1**.

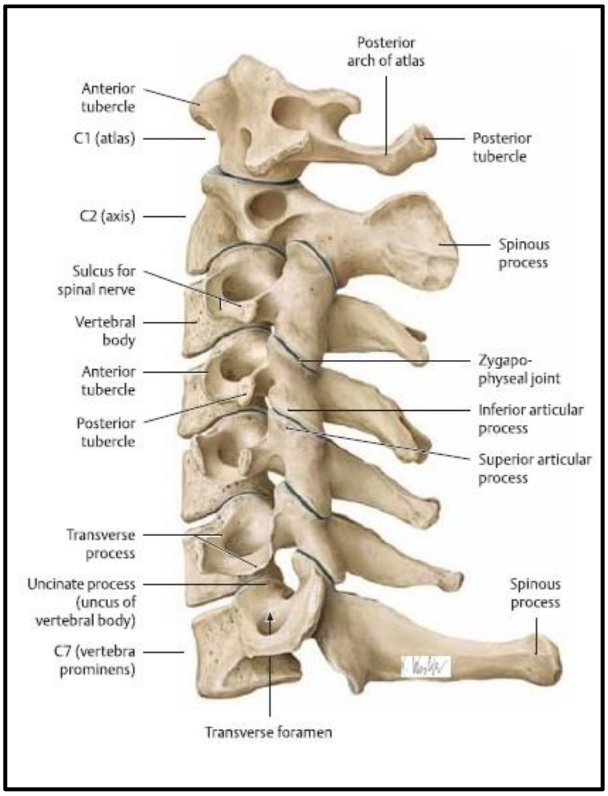

Figure 2.1 Anatomy of cervical spine

(Source: https://www.physio-pedia.com/index.php?title=File%3ACervical_spine_anatomy.jpg&veaction=edit&section=2)

The movements of the cervical spine and degree of movement are dictated by small joints in the cervical spine called zygapophyseal joints/facet joints which consist of superior and inferior articular facets between adjacent vertebrae (Moore, Dalley and Agur 2014: 982–985). The facet joints are surrounded by an articular capsule posterior-laterally and the re-enforced ligamentum flavum anteromedially (Windsor *et al.* 2017). The facet joints consist of an articular capsule that is innervated by a sensory nerve supply at the level of the vertebrae, as well as the vertebrae superior to it (Kallakuri *et al.* 2012).

Mechanoreceptors are types of somatosensory receptors that relay extracellular stimulation information to intracellular signals through a gated ion channel. The external stimuli are often in the form of touch, motion or stretch (Iheanacho and Vellipuram 2021). There are different types of sensory mechanoreceptors in the cervical articular capsule (Ellenbecker, Davies and Bleacher 2012). In the cervical spine, three different types of sensory mechanoreceptors have been found: type I, type II and type IV. Type I are sensitive dynamic and static receptors that fire when the joint I is moving and stationary. Type II are less sensitive dynamic receptors that only fire when the joint is moving, type III receptors are found in the superficial aspect of ligaments in the joints, they are high-threshold, slow adapting fibres and, lastly, type IV are slow conducting nociceptive fibres (Gatterman 2005). These sensory mechanoreceptors work together to maintain proper alignment of the vertebrae in the cervical spine and, in doing so, they also maintain the lordosis of the cervical spine and maintain proper biomechanical function (Halata 1988). However, it has been noted that structural change in the connective tissue such as injury malalignment of joints, aging and degeneration leads to change in some of the mechanoreceptors causing them to adjust to new environment (Halata 1988).

There are several mechanoreceptors, namely Meissner's corpuscles, Pacinian corpuscles, Merkel's disk, Ruffini's corpuscles, Golgi tendon organs and free nerve endings which are described in further detail in this chapter; these also differ in function (Maksimovic *et al.* 2014; Rowen, Likens and Stergiou 2020). The spinal motion segment consists of two vertebrae next to each other and the tissue that connects them to one another, namely the interspinous ligaments, intertransverse ligaments, supraspinous ligament, facet capsular ligament, ligamentum flavum, posterior longitudinal ligaments, anterior longitudinal ligament and the intervertebral disc. This is depicted in **Figure 2.2**.

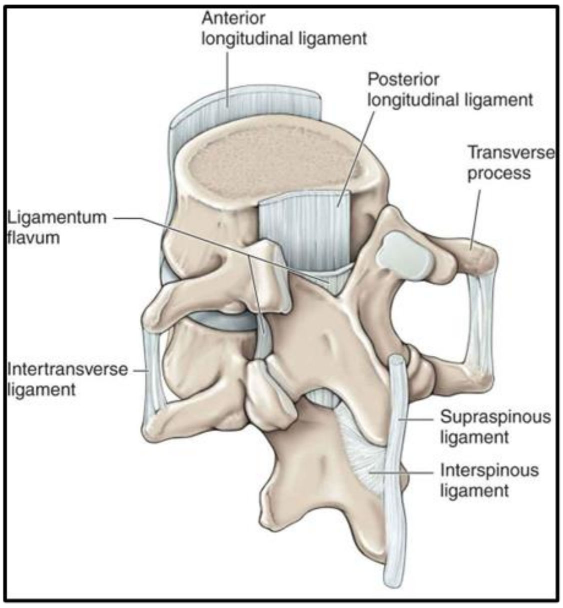

Figure 2.2 Spinal motion segment

(Source: http://hotcore.info/babki/lumbar-vertebrae.htm)

The movements within the cervical spine consist of flexion, extension, rotation bilaterally and lateral flexion bilaterally. The range of motion in the cervical spine is typically 80°/90° flexion, 70° extension, 90° rotation and 25°/45° lateral flexion (Swartz, Floyd and Cendoma 2005). Most movements within the cervical spine are coupled movements and it is very seldom that a uniplanar movement is found (Swartz, Floyd and Cendoma 2005). Abnormal movement of cervical facet joints have been noted to relate to spinal dysfunction (Gatterman 2005). Cervical spinal dysfunction can relate to impairment in factors, such as postural alignment, proprioception and range of motion which can cause cervicogenic dizziness (Sung 2020). Cervicogenic dizziness can cause symptoms that affect balance, such as visual disturbances and instability (Reid *et al.* 2017). Chiropractic care involves the restoration of normal movement to a dysfunctional joint (Nighbor 2018).

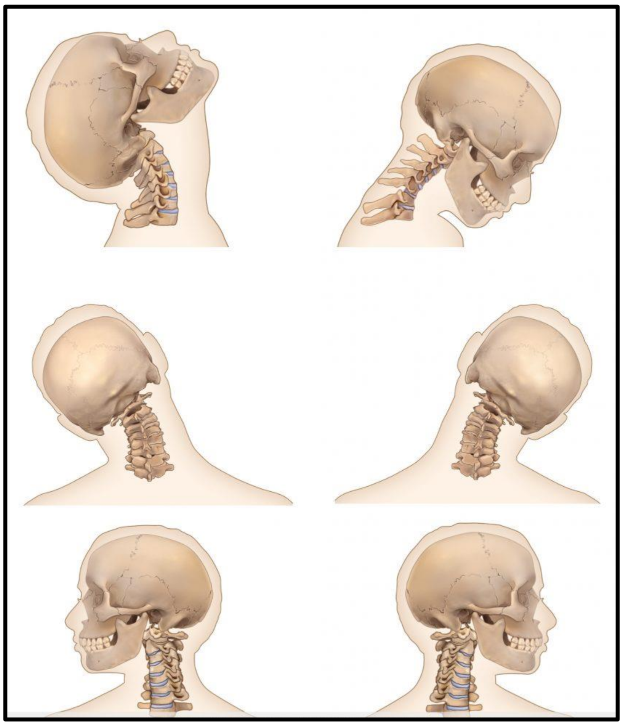

Figure 2.3 Movement of the cervical spine

(Source: www.learnmuscles.com)

Spinal nerves emerge from the vertebral foramina in the spine. Nerve fibres from different spinal nerves are combined and re-ordered so that all the fibres going to a certain part of the body can be combined into one nerve; this is referred to as a nerve plexus (Singh and Khalilil 2021). There are four nerve plexuses emerging from the spinal cord, namely brachial, cervical, lumbar and sacral (Moore, Dalley and Agur 2014). The brachial plexus emerges from spinal nerves in the cervical spine and supplies the upper limb, whereas the sacral plexus supplies the lower limb (Moore, Dalley and Agur 2014).

The lumbar plexus is a web of nerves that emerges just lateral to T12–L5; it supplies sensory and motor function to the lower limb, as well as the abdomen and pelvis (Singh and Khalilil 2021: 1–3). Abnormal curvature or biomechanics in the cervical spine can directly affect the proper functioning of the upper limb, which is dependent on the brachial plexus for normal, optimum functioning (Illes and Johnson 2013). The spinal nerves form connections with the spinal cord. This is one of the places where the peripheral nervous system (PNS) and central nervous system (CNS) meet and connect both structurally and functionally (Guy-Evans 2021), as seen in **Figure 2.4**.

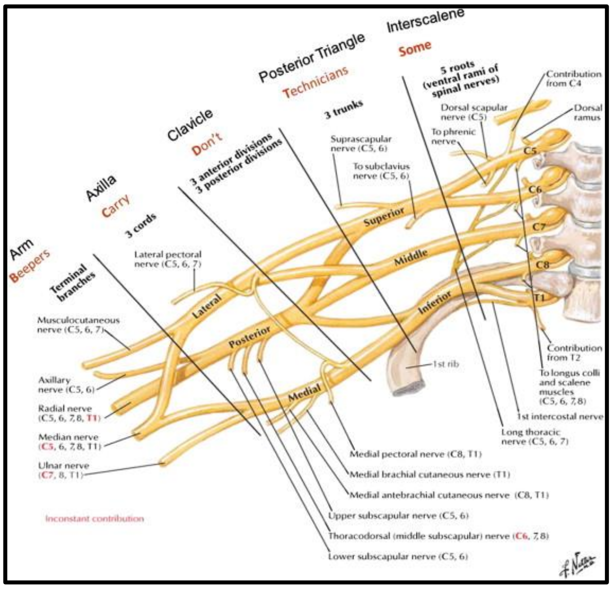

Figure 2.4 Brachial plexus

(Source: https://radiologykey.com/mr-imaging-of-the-brachial-plexus-2/)

2.3 PERIPHERAL NERVOUS SYSTEM

The nervous system is divided into the CNS and the PNS. The CNS consists of the brain, cerebral cortex and spinal cord, as seen in **Figure 2.5,** whilst the PNS consists of all the nerve fibres that exist outside of the CNS (Newman 2022).

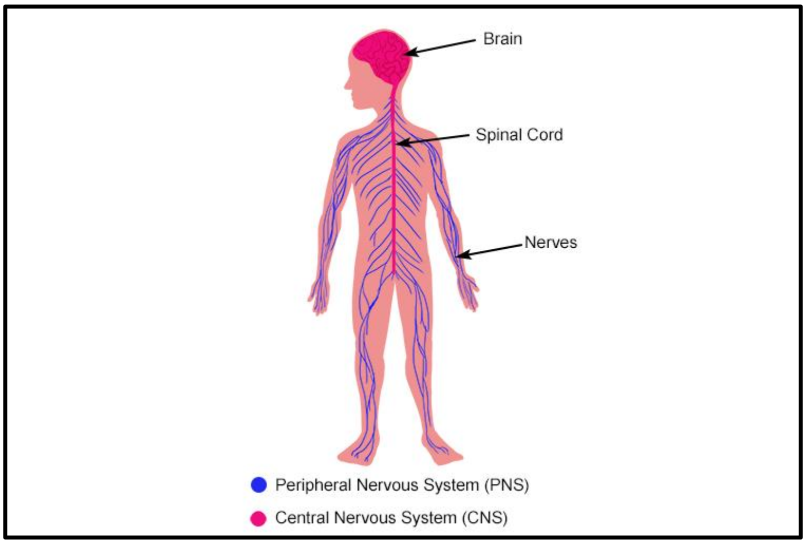

Figure 2.5 Central nervous system and peripheral nervous system

(Source: https://www.guyhowto.com/what-is-nervous-system/)

A clear image of how the rest of the nervous system is divided is laid out in **Figure 2.6**.

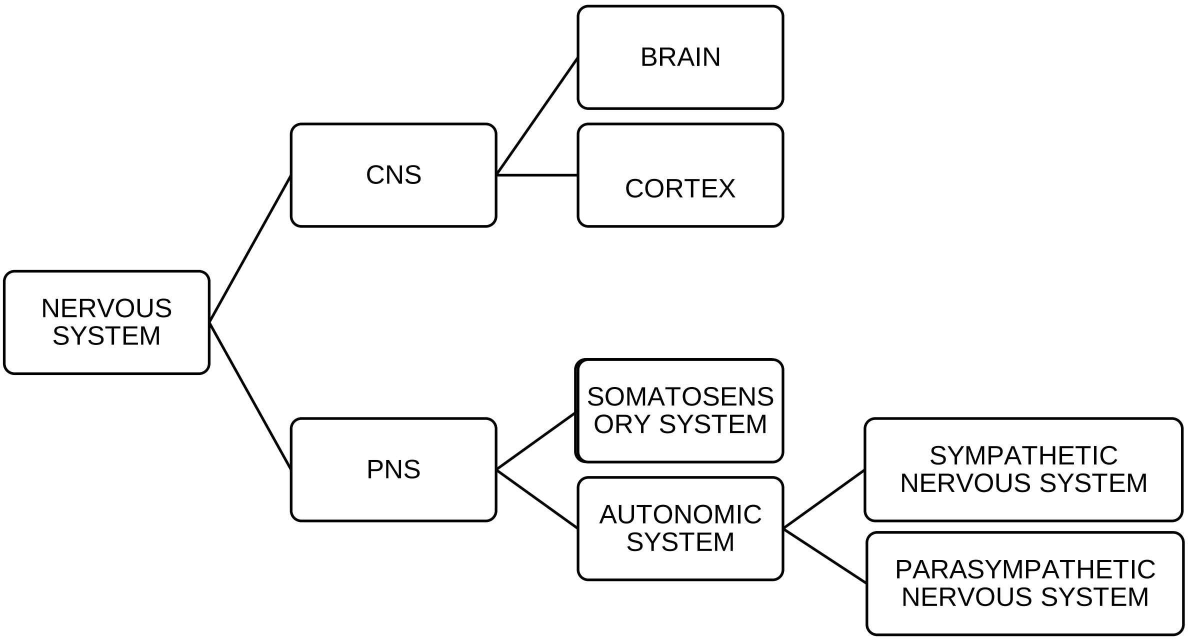

Figure 2.6 The nervous system

The PNS is divided into the autonomic nervous system and the somatosensory nervous system (Waxenbaum, Reddy and Varacallo 2021). The PNS brings stimuli from the peripheral body and organs to the CNS for processing so that the appropriate response can be brought about (Newman 2022). There are spinal peripheral nerves which carry information to and from the spinal cord and cranial nerves taking information to and from the brain stem (Dougherty, Anderson and Tsuchitani 2010).

The PNS also relies on reflex arcs to bring about a faster response to a stimulus. Reflex arcs allow afferent neurons to synapse at the spinal cord, bypassing the brain, activating the neurons at the spinal cord; the response is then sent via an efferent neuron to bring about an appropriate response (Blanchard and Bronzino 2012; LibreTexts 2020). It is also important to understand that the messages from the nerves/neurons are sent via neurotransmitters to the relevant receptor cells throughout the body. Neurotransmitters are chemical messengers that carry information to receptors, after which the body breaks them down or recycles them (Sheffler, Reddy and Pillarissety 2022). Neurotransmitters have different functions: inhibitory (decrease the chance of the target cell taking action), excitatory (encourage the target cell to take action) and modulatory (can communicate with many neurons at the same time) (Sheffler, Reddy and Pillarissety 2022).

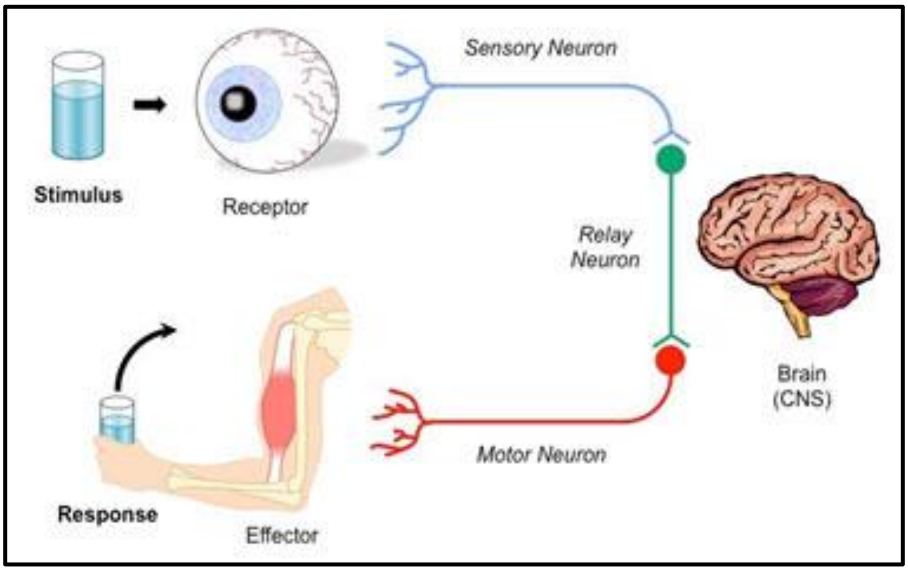

Figure 2.7 Peripheral Nervous system

(Source: Available: https://www.guyhowto.com/what-is-nervous-system/)

The PNS consists of cranial nerves; spinal nerves (including their roots and branches); peripheral nerves, and neuromuscular junctions (Dougherty, Anderson and Tsuchitani 2010). The autonomic nervous system controls the visceral function in the body and the somatosensory nervous system controls voluntary movement in the body (Cherry 2022). The PNS is of particular interest in this study as it supplies impulses to muscles and joints, allowing information to and from these structures to bring about movement and sensation (Waxenbaum, Reddy and Varacallo 2021).

The autonomic nervous system forms part of the involuntary control and functioning of parts of the body. It is also responsible for the so called fight or flight mechanisms, whereby the body involuntarily responds to dangerous or stressful stimuli as well as our rest and digest system, whereby it mediates the unconscious activities of visceral organs, such as digestion (Cherry 2022).

The somatosensory system controls voluntary movement in the body through the skeletal muscle and control of reflex arcs (Sun *et al.* 2022). It is important to understand that although most of the information of the somatosensory system is sent to the brain for processing to bring about a response, some information is sent via reflex arcs, omitting the brain. Most information from the PNS is brought to the spinal cord where it meets the CNS for processing (Waxenbaum, Reddy and Varacallo 2021).

The somatosensory system forms part of the sensory information system of the body together with some specific sensory organs, such as the eyes and ears. It is essential for the postural tone (Kaulmann 2021). It is made up of ascending tracts that bring sensory information from the spinal cord and brainstem. Information is taken to the thalamus, cerebral cortex and cerebellum for processing (Kim, Ying and Shen 2020). It informs individuals about of the outside environment through touch. The somatosensory system also informs one of proprioception, through stimulation of joints and muscles (Kim, Ying and Shen 2020). The cortex plays an important role in balance. This is highlighted in **Figure 2.8**.

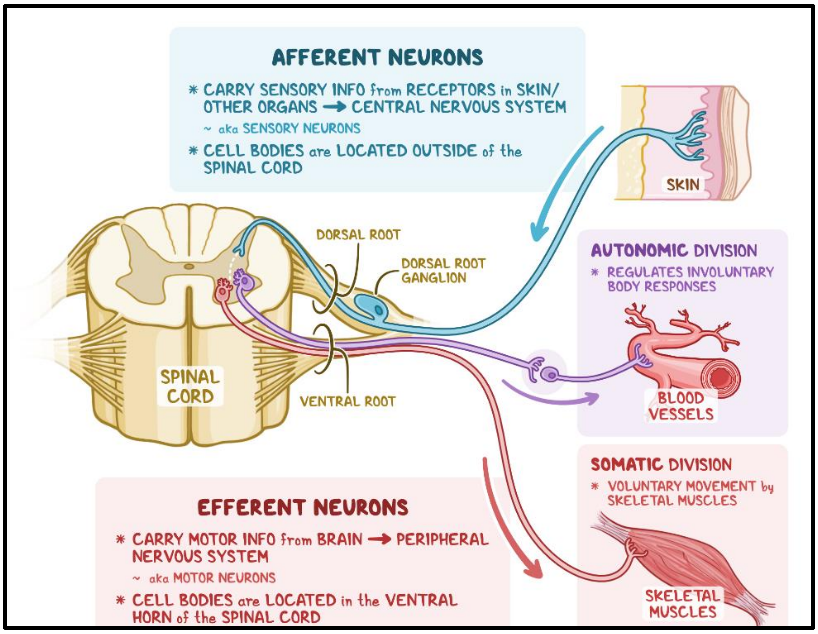

Figure 2.8 Somatosensory system

(Source: https://www.osmosis.org/answers/afferent-vs-efferent-neurons)

The sensory information that is interpreted by the somatosensory system travels along different nerve pathways (Andrusca 2022). These depend on the type of sensory information that is being received, as well as the area from which it is coming in the body. The different nerve pathways known as tracts are described in **Table 2.1** (Dougherty, Anderson and

Tsuchitani 2010). This study focuses on the nerve pathways responsible for proprioception and motor control as they pertain to balance and JPS.

The sensory systems of the body are used for the interpretation of stimuli which allows for the appropriate motor response of the body to these stimuli. Sensory motor integration (SMI) is the delicate interaction between what has been 'sensed' peripherally and the consistent adjustments made by the body to better its motor response to an environment (Kim, Ying and Shen 2020). Disruption to this SMI loop can affect the subsystems related to this loop, such as musculoskeletal components, adaptive mechanisms, anticipatory mechanisms, individual sensory systems and neuromuscular collaboration (Kaulmann 2021). When a spinal cord injury occurs, there is an obvious disruption in the SMI loop which can cause paralysis to certain parts of the motor system in this loop (Matur and Ogie 2017).

The somatosensory system plays an important role in balance and proprioception. It is responsible for the sensory input needed for to maintain proper balance, as well as proprioception. This is done via the detection of environment and relaying this information via the relevant spinal tract, particularly those related to balance and proprioception. The somatosensory system, when functioning accurately, detects our environments through mechanoreceptors, which are explained further on in this chapter, of touch, movement and visual stimulation, and allows for an appropriate response to maintain upright safe posture (Waxenbaum, Reddy and Varacallo 2021).

Table 2.1 Ascending and descending spinal tracts (Andrusca 2022)

Type of spinal tract	What information it carries	Ascending or descending
Anterior spinothalamic	Crude touch	Ascending
Lateral spinothalamic	Pain and temperature	Ascending
Spinocerebellar (unconscious proprioceptive information): -Posterior spinocerebellar -cuneocerebellar -anterior spinocerebellar -rostral spinocerebellar	Proprioception of lower limb Proprioception of upper limb Proprioception of lower limb Proprioception of upper limb	Ascending
Dorsal column-medial leminiscus	Fine touch, vibration and proprioception	Ascending
Pyramidal (voluntary) -corticospinal -corticobulbar	Motor information	Descending
Extrapyramidal (involuntary) -rubrospinal -vestibulospinal -reticulospinal -tectospinal	Motor information	Descending

2.4 CENTRAL NERVOUS SYSTEM (CNS)

The CNS is made up of the three essential parts of the brain, spinal cord and the cortex (Kandel *et al.* 1991). It processes information from the PNS to bring about a response (Kandel *et al.* 1991). It is responsible for the receiving of information from and sending responses to the PNS (Crawford and Caterina 2020). Together with the somatosensory nervous system, the CNS works to bring about an appropriate response to stimuli and a controlled movement of the body (Crawford and Caterina 2020). The CNS is the processing centre of the body (Ludwig, Reddy and Varacallo 2021).

Sensory information from sensory neurons around the body, such as proprioceptors, is sent via afferent neurons to the CNS for processing (Crawford and Caterina 2020). Once this information is processed in the brain, the response signal is sent via efferent neurons to the body to bring about the appropriate response or movement (Ludwig, Reddy and Varacallo 2021). These neurons travel via spinal tracts as pathways between the peripheral body and the brain. The various tracts are explained in **Table 2.1** (Crawford and Caterina 2020). The information sent is either sensory or motor and, therefore, the nerve pathways through which the information is sent are either specifically sensory or motor or both (often termed mixed). This is relevant when trying to identify which pathways are affected during injury or dysfunction (Crumbie 2022).

The interaction between the motor and sensory systems allows individuals to interact with their surroundings, as well as have the ability to complete their relative activities of daily life, such as dressing, brushing teeth, walking, standing on uneven ground and cooking; this is termed sensorimotor integration (Jänig 2022). Effective sensorimotor integration is dependent on strong feedback and connection between the CNS, as well as various other small neuroanatomical systems (Waugh *et al.* 2010). The CNS is constantly using the peripheral afferent information it receives to establish a framework which it can use as a reference (Kandel *et al.* 1991; Jänig 2022).

This framework is constantly being adapted and changed due to new information or movement taking place in the body (Waugh *et al.* 2010). This way the body can adapt and change to function as best as possible in its current environment (Taylor and Murphy 2008). The CNS responds and changes in response to a change in function, which can either be due to the destruction of afferent nerve cell connections or the increase in such (Taylor and Murphy 2008). This results from neural plasticity.

Neural plasticity is a broad term that has acquired many definitions dependant on the domain with which it is being used. In the context used for this research however, neuroplasticity is defined as the change in function or structure of neurons or group of neurons in response to an outward force for example behavioural changes or an internal tensile force, such as diseases like Parkinson's disease (Warraich and Kleim 2010; Dorszweska *et al.* 2020). It has been noted that this can be positive for the individual as it may enhance and restore neurological functions or connections that were lost, but it has also been found that some plastic change can have a negative effect on individuals (Haavik and Murphy 2012). The negative effects of neuroplasticity are caused by maladaptive pathways and synapses often during the attempt to restore function after damage, which can result in pain or dysfunction (Dorsweska 2020).

The CNS can filter the information it receives to process information correctly as it is then able to view stimuli as separate. It is understood that this specific process of the CNS aids in the maintenance of internal bodily posture (Taylor and Murphy 2008). It has been noted that individuals with cervical fixations tend to have alterations in this specific filtering process; this can then directly affect the maintenance of internal bodily posture which can result in a negative effect on an individual's balance (Taylor and Murphy 2008). It has been noted that CSM has a direct effect on this filtering system and can positively influence internal bodily posture (Haavik, Taylor and Murphy 2007). This system, therefore, is important to understand as the CNS plays a vital role in balance and there is a clear link between cervical fixations affecting the proper functioning CNS. This study focuses on the effect of CSM of cervical fixations on balance and JPS.

2.5 BALANCE

Balance is defined as a system which creates the awareness of one's bodily position in space, as well as maintains a desired position (Vuillerme and Rougier 2005; Ivanenko and Gurfinkel 2018). Balance is made up of the proper functioning of three main systems, namely vestibular (ears), visual (eyes) and nervous (proprioception/JPS) (Alcock, O'Brien and Vanicek 2018). These work together to maintain a desired bodily position (Waugh, Grant and Ross 2010). When one of the three facets of balance are not functioning optimally, the other two tend to be enhanced to help compensate (Waugh, Grant and Ross 2010). For example, when an individual is visually impaired, they tend to rely more heavily on their hearing and proprioception for balance and stability (Dunleavy, Lulofs-macpherson and Slowik 2019).

Vision is important for balance as it allows individuals to take in their surroundings and respond appropriately. Light enters the eye, hits the retina, where the light is transferred into electrical signals by photoreceptors, which are then sent via the optic nerve to the brain, where the signals are interpreted as images (Lazarus 2020). It has been noted that upright balance is easier with eyes open than with eyes closed in individuals who are not visually impaired (Assländer, Hettich and Mergner 2015). Various studies have shown an association between different measures of visual acuity (examples include visual acuity, visual field, motion detection threshold) and balance (Willis *et al.* 2013). A cross sectional study in Canada showed that individuals aged 50 years and above with decreased visual acuity had significantly poorer balance than those with better visual acuity (Sorbello *et al.* 2020).

The vestibular system plays an important role in balance. It is used to establish orientation of the head with regard to gravity, as well as degree and direction of acceleration (Lea and Pothier 2019). Self-orientation and the perception of movement are, in part, due to a healthy functioning vestibular system (Zalewski 2015). The vestibular system is a sensory and a motor system. It is responsible not only for being aware of one's movement but also the awareness of an individual's centre of mass in space in response to gravity. It also coordinates the appropriate ocular and postural reflex movements to maintain static and dynamic equilibrium (Zalewski 2015). This is because motor response is dependent on sensory input.

They nervous system facet of balance refers to proprioception which is the body's awareness of where it is and its movement in space without visual cues. It is further explained within this chapter (Rowen, Likens and Stergiou 2020). For an individual to maintain optimal balance and desired bodily posture, it is important that they can shift and respond to different bodily positions and loads acting on the body (Blanchard 2012). One must be able to adjust to the effects of gravity through slight movements of joints, limb and axial positioning. Axial positioning refers to the positioning of the axial body being the head, neck, thorax, abdomen and pelvis (Blanchard 2012). In a normal functioning nervous system, maintaining an upright position relies on the spinal and cortical networks, which is explained in the nervous system functioning (Rubega *et al.* 2021). There are two different types of balance i.e., static and dynamic.

Static balance is the body's response to gravity on a stable surface, whereas dynamic balance is the body's response to movement (Rahal *et al.* 2015). The movement refers to that of the surface on which the individual is standing; it can be unstable or uneven (such as a sponge mat) or the individual themselves are moving (such as walking or running). Static balance is considered to be easier than dynamic balance in execution (Rubega *et al.* 2021).

During static balance, an individual is relatively stationary on a surface that is stable. Static balance requires a slight shift in their posture to maintain an upright stable position. Dynamic balance is the maintenance of a desired body position whilst moving or whilst on a surface that is unstable. Dynamic balance requires constant shifting and adjusting of the body more so than during static balance (Rahal *et al.* 2015). Balance and proprioception can be affected by certain mechanisms and are, therefore, somewhat modifiable. Various mechanisms have been found to cause improvement of proprioception and overall balance including visual aids (glasses), hearing aids, exercise programmes and manual therapy, such as SMT, which can be performed by therapists, such as chiropractors, physiotherapists and osteopaths (Enyinnaya *et al.* 2012).

Balance can be assessed using a variety of tools and tests, such as the Biodex Biosway® portable system stand and reach tests, get up and go tests, Korebalance® and MotionTrak®.

2.6 PROPRIOCEPTION

Proprioception is an important link between the body and the external environment (Rowen, Likens and Stergiou 2020). It forms part of the somatosensory system and is particularly important in this study. It is the ability to register where the body is in space without visual cues (Maier *et al.* 2012). One of the aspects for a healthy human life is being able to move and interact with one's environment for activities of daily living (Xerri 2012). The lower proprioceptive threshold for the perception of body sway during upright standing position, compared with visual and vestibular systems, is one of the reasons proprioceptive inputs play a critical role in postural control (Henry and Baudry 2019).

Proprioception involves stimulation from mechanoreceptors via movements of the body, which register where the body is in space (Waugh *et al.* 2010). Mechanoreceptors are special sensory receptors that are found in muscle fibres, joint capsules and tendons and detect the position of joints, degree of tension in tendons and to what degree the muscles are contracted muscles. They also detect how much effort is needed by the muscles to perform a specific task (Waugh *et al.* 2010). Impulses are sent to the somatosensory area of the cerebral cortex for interpretation; this allows for conscious understanding of the position and movement of the part of the body from where the impulse came, but they are also sent along afferent nerve fibres to the cerebellum for interpretation to bring about a coordinated movement of the body (Derrickson and Tortora 2011).

There are various types of proprioceptive mechanoreceptors which register different sensory stimulus, as outlined in **Table 2.2** (Derrickson and Tortora 2011; Rowen, Likens and Stergiou 2020). Proprioceptive mechanoreceptors are specific sensory receptors which form nervous impulses in response to movement around the body (Rowen, Likens and Stergiou 2020). Even though proprioceptive signals originate from multiple mechanoreceptors, there is a general agreement that muscle spindle receptors provide the primary source of proprioceptive information for postural control (Henry and Baudry 2019).

Joint position sense, proprioception, balance and kinaesthesia are often used interchangeably in the literature. They are very similar in concept and working. The differentiation is understood as the following: JPS refers to the awareness of position and movement related to a single joint in space without visual cues; and proprioception refers to the same concept, within a single joint, as well as collectively of multiple joints within the body, which is also true for balance and kinaesthesia (Ogard 2011; Maier *et al.* 2012). Joint position sense requires stimulation of mechanoreceptors via movements of the body which register a joints' position in space and relay this information to the brain and central neural system for processing and interpretation (Waugh, Grant and Ross 2010). Proprioception includes not only the immediate sensory signal but also a perception, that is used for learning and memory (Bernstein and Nash 2008). This is important in that proprioceptive ability relies on an individual's ability to integrate the sensory signals from mechanoreceptors to determine the position and movement of specific parts of the body. It relies, therefore, not only on the sensory mechanoreceptors but also the CNS integration assessment of the afferent information to perform optimally (Han *et al.* 2016). The differentiation between proprioception and kinaesthesia is that kinaesthesia is the ability to perceive not only the position, weight and resistance of objects in relation to the body such as in proprioception, it also includes the perception of the extent, weight and direction of movement (Bernstein and Nash 2008). Kinaesthesia, proprioception and joint position sense form part of balance. Balance involves the vestibular, visual and nervous systems in order to maintain a desired bodily position and awareness. Kinaesthesia, proprioception and JPS fall under the nervous system aspect of balance (Alcock, O'Brien and Vanicek 2018).

Evidence shows that learnt skill of specific movements is easier for an individual to execute as less central capacity is used to process information during movements with which the body is already very familiar (Han *et al.* 2015). Movements, however, are new and need to be learnt take longer (Han *et al.* 2014). Recent studies have shown that balance control does not only rely on peripheral reflex mechanisms but also on central processing of proprioceptive information (Han *et al.* 2016).

Table 2.2 Types of proprioceptive receptors (Derrickson and Tortora 2011; Rowen, Likens and Stergiou 2020)

Type of proprioceptive receptor	Location	Responsibility and stimulus
Muscle spindle	Embedded in skeletal muscle	-Tensile force -posture and movement
Golgi tendon organs	Junction of tendon and muscle	Tensile force of tendon and contraction of the muscle (slow adaptation).
Joint kinaesthetic receptors:	In and around articular capsules	
Free nerve endings	-In all connective tissue	-Pressure (slow conductivity) both myelinated and non-myelinated.
Pacinian corpuscles	-Connective tissue, joints, periosteum, dermis and internal organs	-Acceleration and deceleration of joint movement, vibration and pressure (quick adapting).
Ruffini's corpuscles	-cutaneous tissue	-They record the sustained pressure (slow adapting) stretch receptors, record sustained pressure.
Meissner's corpuscles	-dermis	-Elongated receptors sensitive to light touch and fine movement.

There are various ways in which to test proprioception (Han *et al.* 2016). The method of joint position reproduction is a commonly used method of testing proprioception and, more specifically, joint position sense. There are two methods for joint position reproduction; one is contralateral limb testing and the other is ipsilateral limb testing. Ipsilateral testing tests the proprioceptive acuity of the limb that has been passively put into a specific position and then asked to reproduce that position. Contralateral testing tests the contralateral limb proprioceptive acuity, which means that if the right elbow is passively put into a degree of flexion, the participant notes the position, the arm maintains this position and the participant is asked to reproduce the same degree of flexion with the left elbow (Han *et al.* 2016). The acuity can be tested using multiple tools, such as a goniometer, digital inclinometer, electrogoniometer (Lee and Han 2017; Romero-Franco, Montano-Munuera and Jimenez-Reyez 2017). Impaired proprioception can affect neuromuscular control and joint biomechanics and, therefore, can contribute to imbalance and risk of falling (Alahmari *et al.* 2017; Ferlinc *et al.* 2019).

2.7 THE ELDERLY

2.7.1 Definition

Elderly individuals are defined as those who are 60 years of age or older, according to the chronological form of the definition by the United Nations (Scherbov and Sanderson 2019). Aging is a natural process that occurs and is accompanied by degeneration and an increased predisposition to injury, with falling being one of the most common mechanisms of injury in the elderly (Hawk *et al.* 2007; Reddy *et al.* 2017).

2.7.2.1 Degeneration and Balance in the Elderly

As aging occurs, there is marked degeneration of most systems in the body (Ferlinc *et al.* 2019). With respect to this study, the focus of age-related degeneration will highlight those which are related to balance. Aging cause structures in the body to become less elastic and weaker (Ferlinc *et al.* 2019). There is a decrease in the release of neurotransmitters; slower peripheral nerve impulse conduction, due to degeneration of the myelin sheath around nerves which contributes to slower reflexes; decreased proprioception, and an overall decrease in balance (Ferlinc *et al.* 2019).

There is a strong link between aging and visual deficit (Sorbello *et al.* 2020). Kahiel *et al.* (2021) reported that individuals aged 45 to 85 years showed that age-related vision loss over a three year period increased the probability of having decreased balance. Age-related visual impairments include cataracts, presbyopia, decrease in contrast sensitivity, macular degeneration and reduction in visual fields (Salvi, Akhta and Currie 2006; Kahiel *et al.* 2021). A study done in the United States of America showed that more than 15% of white women in the population over the age of 80 years had age-related macular degeneration (Friedman *et al.* 2004).

Aging has a largely detrimental effect on the vestibular system as well. Vestibular deficits include reduced hair cells in the inner ear, often resulting in dizziness, vertigo and disequilibrium. Dizziness affects activities of daily living in 30% of individuals over the age of 70 years (Lea and Pothier 2019). Common causes of vestibular dysfunction in aging individuals are polyneuropathy and bilateral vestibular hypofunction (Lea and Pothier 2019).

There is a marked decrease in proprioception and balance as aging occurs (Alahmari *et al.* 2017). Ageing deteriorates gait, strength and balance after the age of 45 to 55 years. It was noted that the decline in ability with age was linear in relationship when it came to specific tests for balance, such as step test, Lord's balance test (eyes open) and Chattecx balance system (Haber *et al.* 2008). Proper muscular and nervous function are imperative for good balance. Chung *et al.* (2016) showed in their study that there was partial denervation at neuromuscular junctions which suggested that axonal degeneration may be the reason for electrophysiological and muscular strength changes during aging.

A group of 12 participants, with the mean age of 75 years, had significantly greater errors, irregular and prolonged movements in comparison to the younger test group with a mean age of 27 years, when testing required interhemispheric (cross body) transfer and memory-based proprioceptive tasks during a study of the effect of aging on proprioceptive acuity of the upper limb, in a study in the United States of America (Adamo, Martin and Brown 2007). The study also highlighted the importance of cognitive function when completing sensorimotor tasks (Adamo, Martin and Brown 2007).

With aging comes neuroanatomical changes, such as reduced grey matter and cortical thickness, which may result in a marked decline in sensory abilities; this may cause an increase in perceptual thresholds and reduced cortical responsiveness (Eulenburg *et al.* 2017). These age-related changes that affect the cortex have an effect on balance and proprioception (Eulenburg *et al.* 2017). Bullock-Saxton, Wong and Hogan (2001), outlined the influence of age on weight-bearing joint reposition sense being a definite decline in joint position sense on partial weight-bearing in the elderly. The degeneration that occurs in the elderly is directly related to impaired balance, gait and proprioception.

Palve and Palve (2019) compared nerve conduction velocities of different age groups (18 to 30, 31 to 45 and 46 to 60) years of age it was clear that patients of an older age had longer latencies, smaller amplitudes, and slower conduction velocities compared with the younger age group, specifically when it came to sensory nerve conduction and peripheral nerve conduction. As individuals' peripheral nerve impulse conduction slows so they have a slower response to a stimulus or change in external environment, such as uneven ground, which results in a delayed response and often an inability to bring about the required response quick enough to avoid stumbling or in many cases falling (Henry and Baudry 2019). This can also be understood with regard to decreased reflexes and proprioception and other components, such as impaired vision, which again will bring about a slowed response to a change in environment, such as stairs, uneven ground or a folded rug, which may result in a fall. This is one of the reasons why aging is such a high-risk factor for falling.

Along with poor vision and environmental hazards, balance and lower limb dysfunction have been noted as important modifiable risk factors for falls among the elderly. This is due to the fact that there are various non-invasive mechanisms of treatment that can help improved these specific risk factors of falls. The mechanisms of treatment include, but are not isolated to, massage, SMT, exercise, appropriate footwear, glasses or contact lenses, management of poly-pharmacy and adaptation of the environment to better suit the elderly; these can help improve balance and help decrease the risk of falling (Enyinnaya *et al.* 2012).

2.7.2.2 Balance and Falls among the Elderly

Falls are defined as an unintentional loss of balance that results in a failure of postural stability (Guccione, Wong and Avers 2012). Falls are often caused by a combination of factors both intrinsic and extrinsic but there is ultimately failure to maintain postural stability. Alterations in balance caused by degeneration tend to play a large role in the increased risk of falls among the elderly (Howcroft, Kofman and Lemaire 2013). The mechanisms for balance and postural control deteriorate with age, resulting in a decrease in balance and an increase in falls risk (Wallmann 2009). The accumulation of these degenerative changes further decrease balance in the elderly and result in a higher risk of falling.

2.7.3 Falls among the Elderly

2.7.3.1 Causes of falls

Falling in the elderly has been noted as a significant problem worldwide (Howcroft, Kofman and Lemaire 2013). The elderly population is considered the fastest growing population group in the world (Terroso *et al.* 2014). It has been stated that one in every three individuals over the age of 65 years old and one in two over the age of 80 years old will fall each year (Ang, Low and How 2020). The frequency of falling increases as age increases (Sharif *et al.* 2019).

With falling often comes a fear of falling. Between 20% and 39% of individuals who fall experience fear of falling, which further limits activity and increases dependency (Sharif *et al.* 2019). Falls are often multifaceted in origin and potentially could be prevented (Holt *et al.* 2016). Since falls are often complicated in cause, it is difficult to focus on all the factors associated with falls and, therefore, a narrower focus has been given in this study of examining proprioception and balance. Falls are divided into two categories of risk factors, namely intrinsic and extrinsic. Intrinsic risk factors focus on the factors associated with the elderly individual, such as impairment of balance, gait and proprioception (Kenny, Romero-Ortuno and Kumar 2017). Extrinsic risk factors focus more on the surrounding factors an individual is exposed to, such as environmental hazards, which include uneven ground surfaces, stairs lacking a rail and poor lighting (Kenny, Romero-Ortuno and Kumar 2017).

Developing countries tend to have higher extrinsic risk factors due to poverty, informal settlements and a lack of financial infrastructure needed to provide safer environments for the elderly (McKinney, MicKinney and Swartz 2021). This leads to the need to focus on lowering the intrinsic factors to compensate for the high number of extrinsic factors.

2.7.3.2 Falls in South Africa

South Africa is a developing country and, therefore, a substantial percentage of the population is in the lower socio-economic income bracket. According to the South African Social Security Agency (SASSA), citizens over the age of 60 years are regarded as pensioners (South African Social Security Agency 2021). A significant number of these individuals rely solely on government pension allowances as a source of income.

Lower to middle income countries have large challenges when it comes to healthcare including poverty, poverty-related diseases, inefficient healthcare systems, training and equipment, inaccessible transportation systems, corruption, political instability, and negative attitudes towards disability (McKinney, McKinney and Swartz 2021). Many of these challenges are highlighted in the study by McKinney, McKinney and Swartz (2021) on disability and healthcare in South Africa. Subsequently, many individuals are at high risk of illness due to factors resulting from poverty. These factors include decreased access to medical care, poor housing, under-education, and overpopulation which also contribute to an increase in the risk factors for falling (Kalula *et al.* 2016).

The more risk factors one is subjected to, the higher one’s risk of falling. Elderly individuals in developing countries are often subjected to a higher number of risk factors for falling (Phelan *et al.* 2015). Developing countries tend to have less environmental infrastructure to support the elderly, such as even paved surfaces for walking especially on sidewalks; many stairs lack railing support or inclines lack stairs, and there is poor state health care to help aid the elderly with treatable visual impairments, hearing impairments and walking aids (McKinney, McKinney and Swartz 2021).

There is a need for research that could aid in reducing risk factors for falls specifically to compensate for the multiple extrinsic risk factors in developing countries that are so vast and numerous and perhaps focus on the reduction of the intrinsic factors contributing to falls. The consequences of falls among the elderly are what contribute to the importance of research in this field (Kim 2016).

2.7.3.3 Physical Effects of Falls

The effect of falls among the elderly has a physical, psychological and financial impact. In Singapore falls account for 40% of injury-related deaths (Ang, Low and How 2020). Each year, around 37,3 million falls that occur in the elderly require health care and 424000 result in death of the faller, according to the statistics found from the World Health Organisation (Terroso *et al.* 2014). Physically, 10% of falls result in serious injuries, including fracture of the hip, other fractures, traumatic brain injury, or subdural hematoma (Appeadu and Bordoni 2022).

Aging causes delayed healing from an incident, and there are high risks of complications from falls, such as infection (Koval *et al.* 2003). The age-related changes that delay healing and possibilities of falls related injuries are vast. Often falls result in fractures due to osteoporosis and age-related degeneration, increasing age causes delayed union and malunion of bone fractures (Foulke *et al.* 2016). A study on aging and healing times found that patients aged 65 years and above have significantly longer healing times than patients aged 18 to 40 (Nikalaou *et al.* 2009). Elderly individuals also have delayed wound healing, due to multiple factors including loss of skin elasticity, neurodegeneration and homeostatic imbalance (Gould and Fulton 2016).

Most fall related injuries result in wounds or inevitably surgical wounds. Age-related degeneration of reduced capacity of keratinocytes and thinning of the dermis make elderly individuals particularly susceptible to wounds as well as delayed healing (Gould and Fulton 2016). Together with natural aging degeneration, it has been noted that many individuals over the age of 65 years have comorbidities which add to the delay in healing of wounds, such as diabetes and hypertension (Gould and Fulton 2016). Healthy, weight-stable men and women, between the ages of 68 and 78, lose approximately 1% of fat-free mass per year. This loss of lean muscle translates to a loss of strength and is a primary predictor of disability (Fantin *et al.* 2007). There is a viscous circle when it comes to falls and the elderly. Falls often are accompanied by injury, which is accompanied by pain and infection management medications, loss of muscle tone, and loss of energy and appetite, which all contribute to further disability and risk of falling (Gould and Fulton 2016).

2.7.3.4 Psychological Effects of Falls

Psychologically, falls can result in depression and dependency (Kenny, Romero-Ortuno and Kumar 2017). A review in Greece by Alexiou *et al.* (2018) highlighted that individuals over the age of 65 years who suffered from hip fractures, had a higher occurrence of detrimental effects of health status and health related quality of life. They also showed that negative psychosocial effects and symptoms of depression related to the injury could increase the severity of the pain and emotional distress (Alexiou *et al.* 2018).

Another study done in Washington highlighted that 10% of the 482 patients over the age of 60 years old suffered severe depressive symptoms post-hip fractures, which resulted in delayed healing and mobility (Cristancho *et al.* 2016). Often, the psychological effects of falls are caused by the fear of falling due to previous falls or a near falling incident (Murphy, Dubin and Gill 2003; Ang, Low and How 2020). This can cause individuals to socially isolate themselves, decrease physical activity and can result in anxiety and depression, all of which add to further risk of falling, creating a detrimental negative cycle (Ang, Low and How 2020).

Around a third of older people develop a fear of falling after a fall, and those who do have a worse prognosis in terms of reduced activities of daily living, loss of self-efficacy and self-confidence, activity avoidance, lower quality of life and increased institutionalisation (Kenny, Romero-Ortuno and Kumar 2017). Falls often result in a financial burden on the injured, due to medical bills, assisted-living care, assisted-living devices and many other unforeseen costs, resulting in anxiety, and stress which adds to the negative psychological state of the individual.

2.7.3.5 Financial Effects of Falls

Financially, post-fall care takes a significant toll on either the state or an individual. Such injuries cost the United States of America $20 billion annually (Howcroft, Kofman and Lemaire 2013). Wound care alone costs the United States more than $25 million per year (Gould and Fulton 2016). Lee *et al.* (2018) highlighted the excessive socioeconomic effect falls among the elderly have on both the country and the individual. Of 2012 participants residing in Korea, 666 individuals succumbed to falls, resulting in direct medical costs equivalent to R3.7 million, this also highlighted the large financial impact falls have in rural communities.

2.7.3.6 Management of Falls

There are various management strategies which aid in the prevention of falls and furthermore in the improvement of balance and proprioception. The management strategies that involve falls prevention are rather vast and often complicated. Management can be individually tailored, multifaceted or singular in strategy (Appeadu and Bordoni 2022). A review on various management strategies by Appeadu and Bordoni (2022) included but were not isolated to vitamin D and calcium supplements, exercise programmes, home assessments and medication review. It was noted that vitamin D supplements increased muscle strength and balance in community-dwellers (Kenny, Romero-Ortuno and Kumar 2017; Appeadu and Bordoni 2022). Exercise programmes that were noted to help improve balance, strength, control and endurance and therefore decreasing falls risk included tai chi, balance training, strength and endurance training (Appeadu and Bordoni 2022).

Medication review is important as there are many inter-drug interactions, as well as isolated drugs, that can cause dizziness, vertigo and imbalance, which increase falls risk that individuals may not be aware of (Kenny, Romero-Ortuno and Kumar 2017). A meta-analysis on individuals over the age of 65 years in Canada revealed that a combination of falls prevention management that involved exercise and visual assessment and treatment was the most strongly related to fall prevention when comparing various fall prevention management strategies (Tricco *et al.* 2017). They also highlighted that combination management strategies tended to have better outcomes than those of isolated strategy (Tricco *et al.* 2017). Often walking aids are used to aid balance and help prevent falls, but walking aids alter the biomechanics of normal bipedal walking by shifting weight forward, resulting in weakness during walking but, ironically, not using the aid would increase falls risk further (Kaulmann 2021).

There is value in management strategies that help improve balance, whilst challenging individuals enough to prevent deterioration or weakness caused by lack of activity or dependency (Kaulmann 2021). Cognitive training has also shown improvements in balance and gait stability in individuals. Mirelman *et al.* (2011) reported that, patients with Parkinson's disease, aged 55 to 79 were given a programme of combined physical treadmill training and cognitive training through virtual obstacles, showed improvements in balance and gait.

Chiropractic has also shown to alter central neural function which plays a significant role in the control of movement and the awareness of ones' body's position in space (Haavik and Murphy 2011). Chiropractic SMT is a non-invasive method of treatment and has been noted to have a positive effect on some risk factors contributing to falls (Enyinnaya *et al.* 2012). Studies have shown that chiropractic spinal manipulative therapy can alter balance and JPS, which are both intrinsic risk factors for falling (Hawk and Strunk 2009; Haavik and Murphy 2011; Holt *et al.* 2016). Chiropractic adjustments have also been noted to alter sensorimotor integration at a cortical level, which affects balance and proprioception (Lelic *et al.* 2016). Lelic *et al.* (2016) recruited participants that were pain free with two adjustments being administered in separate sessions and not isolated to a specific spinal section. The practitioners administering the adjustments had 15 years or more of experience (Lelic *et al.* 2016).Chiropractic care can, therefore, be noted as a significant management strategy for falls risk.

The study by Lelic *et al.* (2016), however, involved individuals who had no current pain and the two adjustments administered in separate sessions were not isolated to a specific spinal section; they were also administered by practitioners with 15 years or more experience.

2.8 DYSFUNCTIONAL FACET JOINTS

A dysfunctional facet joint or spinal fixation is a spinal motion segment with altered joint movement, function or alignment (Gatterman 2005). Fixations have effects on the surrounding soft tissue, cervical spine joints and nerves (Leach 2004; Haavik 2012). There are multiple possible causes of fixations including, but not isolated to, muscles spasm, disc dysfunction, trauma, poor posture, whiplash, oedema and adhesions; it is very difficult, if not impossible, to isolate the exact primary cause of fixation (Gatterman 2005).

Spinal tracts relay information that aid in the control of balance, JPS, movement and muscle activity. When fixations occur, it can affect this relay of information through the tracts and affect the function for which those signals were necessary. Haavik and Murphy (2011) highlighted this in their study done in New Zealand, where they found that fixated spinal segments can cause altered afferent input which can also affect central neural plastic change.

Haavik, Taylor and Murphy (2007) noted that individuals suffering from cervical spine fixations had an altered ability to filter sensory information, which is used predominantly to aid in postural control (Tinazzi *et al.* 2000). It was also noted that the ability to filter relevant information may be disrupted in individuals with cervical fixations and, therefore, the central neural function may be altered (Haavik and Murphy 2011).

Lelic *et al.* (2016) found that two sessions of SMT of a dysfunctional spinal segment can alter SMI, as well as influence the cortex of the brain, specifically the pre-frontal cortex, which is involved in motor control. The study involved subclinical, male participants with a mean age of 25.6 years old and was conducted in Denmark (Lelic *et al.* 2016).

Holt *et al.* (2019) showed in their study on stroke survivors, that a single session of chiropractic SMT on a dysfunctional spinal segment increased specific muscle strength by 64.2% when compared with a control group. The changes in muscle strength appeared to be modulated by cortical processing rather than at a spinal level. This was identified through changes in H-reflex, which is a measure of spinal excitability, and V-wave amplitude, which is a measure of cortical drive. The Hoffmann reflex (H reflex) is used to assess motor units activated by the afferent pathway and volitional wave (V wave) is an electrophysiological variant of the H reflex. They reflect the efficiency of transmission of Ia afferent-α motorneuron synapses (Aagaard *et al.* 2002). The study was done in Australia and involved 12 male participants with an average age of 48 years; the intervention involved diversified technique spinal manipulation or instrument assisted manipulations (Holt *et al.* 2019).

With regard to pain and fixation, often pain is a symptom related to a spinal fixation and dysfunction, but it does not need to be present for a spinal fixation or dysfunction to be present (Gatterman 2005). It has been noted that the sensory input to higher processing centres in the brain are impaired when fixations occur. Haavik and Murphy (2007) highlighted that the afferent feedback of fixated segments alters the feedback received and processed from the peripheral nerves and the spine. This affects the SMI. Therefore, it may have an indirect or direct effect on JPS, balance and even muscular stimulation (Haavik and Murphy 2007).

2.9 SPINAL MANIPULATIVE THERAPY

Spinal manipulative therapy is a form of treatment used by various practitioners, such as chiropractors, osteopaths and physiotherapists to restore movement to a dysfunctional joint. This is done using manual therapy or a device that helps restore movement and normal functioning, it relieves pressure on joints, decreases inflammation and improves nerve function (Hurwitz 2012; Triano *et al.* 2013). The effects of manipulation are far reaching. Research studies have highlighted the increase in range of motion, relief of pain, inflammation, spinal dysfunction and muscle spasm (Leach 2004; Gatterman 2005; Bronfort *et al.* 2010). Chiropractic manipulations vary in technique, however, overall, they attempt to achieve the same goal which is to increase normal motion and decrease dysfunction of a specific fixated joint and its surrounding structures. **Table 2.3** describes the various techniques used to deliver SMT (Nighbor 2018).

Table 2.3 Types of spinal manipulative therapy

Type of Spinal Manipulative Therapy	Description
Diversified technique	Used predominantly by chiropractors, it is a high velocity, low amplitude specific thrust on a dysfunctional joint. To repair dysfunctional joint and allow improved mobility.
Spinal manipulation/manual	Used by chiropractors and physical therapists, similar to the diversified technique however much gentler without a definite thrust; uses stretching and movement of the joint to promote healing and relieve pressure on the joints.
Thompson drop table technique	Requires a specialised table, that have padded platforms that have been specifically designed with a drop mechanism; the platform drops a couple of millimetres with the care providers' thrust to restore movement and promote healing to a dysfunction joint; it resembles a light vibration.
Gonstead adjustment	Restores normal disc alignment and restores movement; it is done with the patient sitting or lying and the practitioner's hand is used to make specific contact on the joint being manipulated.
Activator technique	Uses a handheld, spring loaded device (mechanical force manual assisted) to administer an impulse (0.3J) to the joint in question to adjust the tone of the nervous system; is used for various conditions.
Flexion distraction	Uses a special table which distracts and flexes the spine in rhythmic motion, often used to treat disc injuries.
Spinal decompression	Uses a special table which gently decompresses the spine by stretching it out, used to treat disc bulges and herniations.
Torque release technique	Neurological-based manual/instrument assisted treatment.

This study used the diversified technique. Due to the training of the researcher in this specific technique, it is the chosen technique taught to students at the educational institutions teaching chiropractic in South Africa. The technique holds three basic principles of the restoral of spinal alignment, repair of a dysfunctional joint and enhancing proper movement. It is the most common technique used by chiropractors worldwide (Nighbor 2018). There is dispute over the founder of the diversified technique, but credit can be given to Palmer, Reinert and Janse (Nighbor 2018). Due to the dispute of the founder, there is also dispute as to when it was discovered, but 1895 is accepted as the founding year of chiropractic and the diversified technique attributed to Palmer (Nighbor 2018). This technique is relatively safe when used on healthy elderly individuals. Cagnie *et al. (*2004) noted that although post SMT reactions are relatively common, they are predominantly benign, mild and short in duration in healthy individuals consisting mainly of minor muscle stiffness and headache.

2.10 THE EFFECT OF SPINAL MANIPULATIVE THERAPY ON BALANCE AND JOINT POSITION SENSE

It has also been noted that cervical spinal manipulation (CSM) influences the sensory filtering system of the peripheral proprioception. Haavik, Taylor and Murphy (2007) noted in their study using somatosensory evoked potential (SEP) technique that individuals aged 18 to 40 years with neck stiffness and pain in New Zealand, that SMT of the cervical spine aids this sensory filtering system which has a direct positive effect on the postural stability of an individual. Cervical spine manipulation of dysfunctional cervical joints can cause an increase in JPS. Another study done in New Zealand by Haavik and Murphy (2011) showed that individuals with a mean age of 25.7 years, with asymptomatic subclinical neck pain, have decreased elbow JPS. Furthermore, they showed that CSM of dysfunctional segments in individuals with asymptomatic subclinical neck pain can improve their JPS accuracy of the upper limb. The study used an electrical goniometer to test JPS and used the diversified technique of SMT.

Rogers (1997) revealed in his study on the effect of cervical manipulation on individuals suffering with neck pain on pain rating and proprioception, that there was a mean improvement of 41% of proprioceptive accuracy, as well as a 44% reduction in pain rating in participants after CSM over a four week period. The study used a laser cap device to perform the reproductive proprioceptive test.

Nolan (2010) showed an improvement in balance after CSM of individuals between the ages of 18 and 45 in South Africa using the Biodex Biosway® portable balance system. McKay (2018), noted in South African individuals aged 18 to 35 that there was a statistically significant increase in balance using the Biodex Biosway® after CSM treatment of a dysfunctional joint. Fernandez *et al.* (2018) noticed in their study in Spain, containing 54 participants who all had chronic mechanical neck pain, that the group of participants receiving SMT had a decrease in joint position sense error when compared to that of the group that received placebo SMT. The study looked at the kinaesthesia of the cervical spine rather than the upper limb or extremity. A similar study by Palmgren *et al.* (2006) showed an improvement in head repositioning accuracy and decrease in cervical pain intensity after receiving chiropractic treatment. The study had a mean age of 31.9 years and did not regulate the type of chiropractic treatment used for each participant.

Holt *et al.* (2016), indicated that SMT of any fixated area improved both JPS and balance in individuals aged 65 years or older, over a 12 week period based in New Zealand. The study used a computerised balance platform (CAPs Lite Computerized Posturography System) to test balance, and an angle reproductive test that used potentiometers in order to take goniometric measurements of the ankle which was placed on a swivel board to test JPS (Holt *et al.* 2016). The study incorporated 12 different chiropractic practitioners to administer treatment to different participants. There was no specific regulation on the exact technique administered for each participant. The techniques included high-velocity, low-amplitude, table-assisted, and instrument-assisted adjustment approaches and, therefore, presented difficulty when reviewing the data as it lacked a regulation of treatment. These variables were more controlled in this current study.

Most of the aforementioned studies excluded individuals over the age of 60 years except for a study conducted by Holt *et al.* (2016) in Auckland New Zealand, in which the tested dynamic balance was at a setting which was too difficult for participants to complete, thereby, making the balance results statistically insignificant. A theory called the proprioceptive insult hypothesis noted that CSM at higher levels influence the medulla oblongata as well as the cerebellum (Beck 2011). Since the medulla is the sight of the decussation of spinal tracts which directly relay proprioceptive information to the upper limb (Cagnie *et al.* 2005), the improvement of JPS could, therefore, be attributed to the effect upper CSM had on the tracts, related to the medulla oblongata according to the proprioceptive insult hypothesis (Gatterman 2005).

The discussed studies all highlight the positive effects of CSM on balance and JPS, however, there is still a paucity in the literature supporting the effect of CSM on static balance in the elderly.

2.11 CONCLUSION

There is evidence to support the improvement of balance and JPS through the CSM of fixated/dysfunctional joints through its effect of the sensory filtering system of the body, as well as the effect on sensory motor integration. However, there is very little evidence to show the effect of SMT of the cervical spine on balance and JPS in the elderly. Due to their age-related degradation of balance and high risk of falling, the elderly are a clinically relevant population. There is a paucity in clinically significant literature to clearly outline the effect CSM on balance and JPS in the elderly.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The research procedure is presented in this chapter. This includes an explanation of the study design, the advertising, recruitment of the participants, the sample size and the methodology. The intervention is explained and the specifics of the measurement tools used to collect and record data for this study are also discussed. The setup and procedure for data collection are discussed along with the validity and reliability of all the equipment used.

This chapter details the methods used for statistical analysis and the ethics around this study.

3.2 RESEARCH DESIGN

This study used a quantitative experimental pre- and post-test study design and also included elements of a quasi-experimental design. A quantitative study involves the objective collection of numerical data that can be analysed and used for statistical analysis to explain a phenomenon or a generalisation of a specific group of individuals (Sheard 2018). Experimental research involves tracing the cause and effect relationships between defined variables to test or construct specific theories (Knight and Kenneth 2010). A quasi-experimental design differs from a true experimental design in that it does not have randomly assigned groups, this is true for the pre-post test design of this study (Sheard 2018). This study design was suitable as the data collected for both balance and JPS was both objective and numerical and was, furthermore, used for statistical analysis and understanding of the cause-and-effect relationships between variables involved in this study. This design is limited in that it does not allow for randomization (Schweizer, Braun and Milstone 2016).

Pre- and post-test study design refers to the testing of something specific (in this case of balance and JPS) of individuals prior to an intervention and then immediately after the intervention (in this case chiropractic SMT) to see the immediate effect of the intervention of what was being tested. This method was used to see the effect of SMT on balance and JPS. It decreased the number of uncontrolled variables which could have affected the data of the study, as well as eliminating the dependence on the compliance of each patient to return for continued assessments (Dimitrov and Rumrill 2003).

3.3 STUDY LOCATION

This study took place at a private chiropractic practice in a medical centre and at the Durban University of Technology (DUT) Chiropractic Day Clinic (CDC) once_permission was obtained from the Institutional Research Ethical Committee (IREC) (Appendix A), the owner of the chiropractic practice (Appendix B), the DUT CDC Director (Appendix C) and the Research Director at the DUT (Appendix D).

3.4 STUDY POPULATION

The study population consisted of participants who resided in the eThekwini Municipality who were 60 years of age or older and who met the inclusion criteria.

3.5 RECRUITMENT METHOD

The participants were recruited by means of advertisements (Appendix E1/E2) which were placed at the DUT CDC at local eThekwini supermarkets, old age facilities and libraries, once the relevant authorities (Appendix F) had given permission. In addition, prospective participants were recruited by word of mouth. Prospective participants who responded to the advertisements (Appendix E1/E2) were contacted by the researcher and underwent a telephonic screening (Appendix G1/G2) to determine their eligibility.

3.6 SAMPLING PROCESS

3.6.1 Sampling Method and Sample Size

This study was a pre-post study with a chosen sample size of 30 participants. To avoid a case in which there was no effect of the intervention, a null hypothesis with the effect size needed to be 0.53 at 80% power which gave a significance level of 0.05%. This ensured that the sample size produced results that could be seen as statistically relevant, information given via email by statistician Tonya Esterhuizen, on 10 October 2020.

Below is the formula used to calculate sample size (Esterhuizen 2020).

T tests - Means: Difference between two dependent means (matched pairs)

Analysis:	Sensitivity: Compute required effect size		
Input:	Tail(s)	=	Two
	α err prob	=	0.05
	Power (1-β err prob)	=	0.80
	Total sample size	=	30
Output:	Noncentrality parameter δ	=	2.8987428
	Critical t	=	2.0452296
	Df	=	29
	Effect size dz	=	0.5292356

3.6.2 Inclusion Criteria

- Participants aged 60 years or older.
- Participants with the presence of one or more cervical spine restrictions. Only one restriction will be adjusted; the segment deemed most restricted was isolated and adjusted.
- Participants who signed the informed consent form.
- Participants who were able to flex and extend their dominant arm at least 30º.
- Participants who were able to fully extend their dominant arm.
- Participant with or without pain.

3.6.3 Exclusion Criteria

- The presence of contra-indications to SMT, such as atherosclerosis, vertebrobasilar insufficiency, aneurysm, tumours, fractures, severe sprains, late stage osteoarthritis, clotting disorders, osteopenia, space occupying lesions, diabetic neuropathy, malingering, hysteria, hypochondriasis and Alzheimer's disease (Bergmann and Peterson 2002: 107).
- If considered to be at risk of suffering an adverse event due to chiropractic care based on their clinical history (hypertensive, recent history of trauma to head or neck, recent surgery within three months to neck or head).
- Unable to remain standing unassisted for a minimum of one minute (as this was required for the testing of balance).

- Other reasons for impairment of balance, such as Meniere's disease, ear infections, hypotension, blurred vision, vertigo, ruled out during the physical examination (Whitman 2019).
- If the participant was wheelchair bound.
- If the participant had had cervical SMT in the last four weeks (Farlex 2011). This was to ensure there was an adequate washout period which helped to reduce the external factors that may have affected the outcome of this study.

3.7 INTERVENTIONS

3.7.1 Motion Palpation

Cervical spine manipulation was applied to the most restricted segments found on motion palpation of the cervical spine. This was performed according to the diversified technique described by Bergmann and Peterson (2011) which involved a high velocity, low amplitude force to a restricted joint segment to restore normal or improve range of motion.

3.7.2 Chiropractic Cervical Spine Manipulation (CSM)

The direction in which the restriction was found dictated the specific manipulative technique used, i.e., lateral flexion (LF), posterior to anterior rotation (PA), anterior to posterior rotation (AP), flexion and extension.

C2-C7:

Participant position (PP): Supine.

Contact Point: Index/ middle finger of contact hand or thumb/web of contact hand.

Indifferent hand: Cradled the head and neck on the contralateral side to the contact hand, providing as much support to the head and neck as possible.

Segmental contact point (SCP): Transverse process of vertebra (TVP).

AP restriction (flexion): Skin slack was removed from the anterior aspect of the restricted segment TVP all the way to the contralateral side into a rotation where PA force impulse was applied.

PA restriction: Skin slack was removed from the posterior SCP in a rotation; slight lateral flexion applied over the contact point and a PA impulse force was applied.

LF restriction: Skin slack was removed; the neck was then laterally flexed over the fixation until resistance was felt; then slight PA rotation was applied, and the impulse form was applied lateral to medially.

Extension restriction: Head and neck were placed into extension contact hand on the posterior aspect of restricted TVP, slight lateral flexion to lock joint; once skin slack was removed a PA impulse force was applied to the joint.

<u>C0–C1:</u>

Participant position (PP): Supine head turned so that the dysfunction side faces upward.

Researcher's position (RP): Stood at the head of the bed facing the participant.

Contact point: Hypothenar.

Indifferent hand:

Flexion: Cradling the contralateral side supporting the chin.

PA Rotation: Cradled the contralateral side supporting the neck.

Lateral Flexion: Cradled the contralateral side supporting the head.

Extension: Cradled the contralateral side supporting the head.

Segmental contact point (SCP):

Flexion: The mastoid hand cupping the ear; fingers facing the eyes of the participant.

PA Rotation: The mastoid hand cupped the ear; fingers faced the chin of the participant.

Lateral Flexion: The mastoid, hand cupped the ear, fingers faced the top of the head of the participant.

Extension: The mastoid hand, cupped the ear, fingers faced upward between the vertex and eye of the participant.

Flexion: Skin slack was removed, slightly flexed and inferior to superior impulse force was applied.

PA Rotation: Head was rotated away from the contact (upper) side, until resistance, skin and joint slack was removed and thrust was applied posterior to anterior.

Lateral Flexion: Contact side up, the head was laterally flexed over the fixation, joint and skin slack was removed and a thrust was applied lateral to medially.

Extension: Head was turned slightly away from contact point and extended with both hands. Once skin and joint slack was removed, impulse thrust was applied posterior to anterior and superior to inferior.

3.8 MEASUREMENT TOOLS

The measurement tools used for the study included the Biodex Biosway® portable balance system and the elbow goniometer.

3.8.1 Biodex Biosway® Portable Balance System

This tool is manufactured by Biodex and is used to measure the ability of an individual to maintain the body's centre of mass within its base of support. It is a base plate on which the individual stands to assess their postural sway due to the shift of the body's centre mass over the plate and in this way assesses static balance. The machine uses a system called the "modified clinical test for sensory integration and balance", which incorporates numerous strain gauges to assess changes in the amount of pressure exerted by a participant's feet.

Sway index is then used to gauge the degree of steadiness and balance of the individual, with regard to the amount of sway the individual exhibits. The higher the sway index, the less steady/balanced the individual is. This device has features that enable the testing of both static and dynamic balance which refers to the steadiness of the base plate. For the purpose of this study static balance was tested (Cachupe *et al.* 2001). This system was found to be valid and acceptable for clinically testing balance (Dewan *et al.* 2019). Cachupe *et al. (*2009) found this test to be reliable, with overall stability index reliability being (0.94).

The Biodex Biosway® portable balance system was set up for static balance testing, and the participant was then asked to stand on the machine and their details were put into the machine to establish foot position, age and height. The participant was then asked to stand as still as possible in the centre on the base plate and their sway index was measured for 20 seconds pre- and post-intervention.

3.8.2 Elbow Goniometer

This tool was used for measuring the angle of the elbow joint through a specific range of motion. It was also more specifically used to measure JPS of the elbow joint. An individual's elbow was set at a specific angle of flexion by the researcher using the goniometer. They were then asked to reproduce the initial angle given to them, while blindfolded. Their accuracy in reproducing the initial given angle was then measured with the goniometer of the elbow. It was affordable and simple to use. It was deemed as a reliable and valid tool for measuring joint position sense (Amir, Julie and Philippe 2016). Intra-examiner reliability of the goniometer test was noted as excellent (>0.80) however inter-examiner reliability was low (0.375-0.475) (Herrero *et al.* 2011). This study used intra-examiner testing.

Permission to utilise the portable measurement tools (BBPBS) off campus was given by the Head of the Chiropractic Department and asset control clerk at the DUT (Appendix J1/J2)

3.9 STUDY PROCEDURE

Participants who were interested and contacted the researcher underwent a telephonic screening process (Appendix G1/G2). Once the participant met all the requirements, an appointment was made at private chiropractic practice in a medical centre and/or the DUT CDC. The participant and the researcher were required to wear a mask throughout the process. Upon arrival, the patient had their temperature taken, their hands were sanitised and they underwent a COVID-19 screening questionnaire (Appendix H1/H2) due to the global COVID-19 pandemic at the time.

The participants were informed that they fall under the category of high risk for COVID-19 and were requested to read and sign a COVID-19 consent form (Appendix I1/I2) before they were allowed to participate in the study. The researcher then gave a verbal explanation of the research and what was expected from the participant, at which point the participant was given an opportunity to ask the researcher any questions relating to the research. The participant was then informed that they were free to withdraw from the study at any time. Thereafter, the participant was given a letter of information and an informed consent form (Appendices K1/K2 and L1/L2) to read and sign before they were allowed to participate in the study.

The research room and all equipment used was sanitised before and after each patient. Prospective participants were screened by the researcher for research eligibility by completing a consultation which consisted of a case history (Appendix M), physical examination (Appendix N) and cervical spine regional (Appendix O), to determine if they met the study’s inclusion criteria. If they did not meet the inclusion criteria during these screenings and examinations, they were excluded from the study, which was the case for some individuals.

A pilot study was not conducted, however all the apparatus and paperwork was tested, used and understood before the research study was conducted.

Each participant was connected to the elbow goniometer on the elbow joint of the dominant arm, with eyes closed. The elbow joint was then put into a specific angle that was measured by the elbow goniometer measuring tool. This reading (angle) was recorded on the data collection sheet (Appendix P). The arm was then fully extended and placed at an anatomical neutral position. The participant was asked to reproduce the exact angle as before without assistance. Once the patient had confirmed they were in the position, the angle of the elbow was taken again using the elbow goniometer and the angle was recorded on the data collection sheet (Appendix P). The difference between the two angles measured indicated JPS accuracy.

The participant was then set up for the balance testing using the BBPBS; they were required to remove any footwear. The BBPBS was set to stable postural stability testing of sway index. The participant was asked to stand on the BBPBS machine for 20 seconds with their eyes open, to assess their sway index. The higher their sway index, the poorer their balance. The sway index was then recorded on a data collection sheet (Appendix Q).

Following CSM, balance and JPS measurements were taken again using the same method as the pre-intervention procedure and these measurements were recorded as post-intervention measurements on the respective data collection sheets (Appendices P and Q).

All readings obtained from the BBPBS and elbow goniometer were captured on a Microsoft Excel spreadsheet before being sent to a statistician for statistical analysis. The spreadsheet and files were safely stored and confidentiality was ensured as only the researcher and the research supervisor and co-supervisor had access to the data.

3.10 DATA ANALYSIS

This research used the statistical software IBM SPSS version 27 to analyse the data that were collected. The quantitative variables used the Shapiro-Wilk's tests to assess normality. Continuous normally distributed variables were summarised using the descriptive data statistics, such as mean and standard deviation. Categorical variables were summarised using frequency counts and percentages. Quantitative variables that were not normally distributed were presented as median and inter-quartile range. The outcome variables were not normally distributed (Shapiro-Wilk's $p<0.01$) and, because of this, the intervention and control conditions were compared in pair samples using nonparametric tests. To determine the difference on the control and intervention condition, a Wilcoxon signed ranks test was used, with a significance level of 0.05, information given via email by statistician Tonya Esterhuizen, 31 May 2022.

3.11 ETHICAL CONSIDERATIONS

Institutional Research Ethics Committee (IREC) approval was obtained from DUT before commencement of the data collection procedure (IREC 063/21).

- Each participant went through a screening process in order to exclude any high-risk individuals from the study; this ensured non-maleficence was maintained and each participant's findings were also presented to a clinician prior to intervention, to further assess any risk of harm to each candidate by being included in the study.

- Each participant was required to read and sign a letter of information and informed consent (Appendix J and K) which were also verbally explained to them before they could participate in the study. This allowed autonomy to be maintained throughout the study.
- All participants' information was kept confidential and abided by the POPI act whereby their information was kept private. Each participant was presented in the data as a code number for identification and no other identifying information was shared. The information of each participant was shared solely with the clinician on duty and the researcher. Information about the participant was stored in a safe private filing system on DUT campus, with no public access.
- The participants were properly informed with regard to the research procedure. All data collected were coded and safely stored in the clinic. The data will be stored for five years before it will be shredded as per DUT Chiropractic Clinic protocol.
- No care was withheld from patients needing it. Participants were allowed to withdraw from the study at any given point in time.
- This study was done with the intention to add to the information around balance, JPS and specifically geriatrics. This study investigated a treatment that could potentially help benefit individuals and help reduce the harm caused by imbalance.
- This study was done to help and care for individuals, whilst excluding any participants at high-risk of danger or injury and therefore maintained beneficence.

3.12 Summary

This chapter has described the research protocol utilised in the study and explained the manner in which data was obtained and analysed. The next chapter will present the findings of the study.

CHAPTER 4

RESULTS

4.1 INTRODUCTION

This chapter describes the results that were obtained from the data collected over the duration of this study. IBM SPSS version 27 was used to analyse the data. The Wilcoxon signed ranks test was used to determine statistical relevance as it is used to compare results conducted with same tested measurements on a single sample. To see if the mean ranks differed, this test used a significance level of 0.05 for statistical relevance. The measurements included:

1. Demographics in terms of age, gender and race. Those were all recorded in the case history of each participant.
2. Balance (static) in terms of a sway index which was represented as a score out of 14, with 14 being the most possible sway and zero being no sway. It was measured using the Biodex Biosway® portable balance machine.
3. Elbow joint position sense accuracy was measured in degrees using a goniometer and measuring the accuracy of JPS.

This study was based on the following hypotheses:

<u>Null hypothesis:</u>

It is hypothesised that there will not be an improvement in both the sway index and JPS readings post-SMT intervention.

<u>Alternate hypothesis:</u>

It is hypothesised that there will be an improvement in both the sway index and JPS readings post-SMT intervention.

4.2 DEMOGRAPHICS

The participants included females and males of no specific ethnicity, who were aged 60 years and above, who responded to the advertisement and fit the inclusion criteria of this study. **Table 4.1, 4.2 and 4.3** summarises the age, gender and ethnicity of the participants involved in the study.

4.2.1 Age

The mean age of the participants in this study was 71.07 years of age; the maximum age was 90 years, and the minimum age was 61 years. This is clearly illustrated in **Table 4.1**. The standard deviation which pertains to the general variation of the data, in this case age, is 6.198 of the 30 participants in this study. Few participants were over the age of 80, the eldest participant was an outlier and therefore skewed the data on age. This may have affected the research information that pertains to the elderly, there is a vast increase in degeneration as aging continues.

Table 4.1 Age

Title	Value
Number (N)	30
Mean	71.07
Standard deviation	6.198
Minimum	61
Maximum	90

4.2.2 Gender

In this study, 76.7% of the participants were female and 23.3% were male. It is clear that there was an uneven distribution of male and female participants. **Table 4.2** shows the number and percentage of male and female participants who participated in this study.

Table 4.2 Gender distribution

Gender	Frequency	Percent
Female	23	76.7
Male	7	23.3

4.2.3 Ethnicity

Table 4.3 shows the number and percentage of the ethnic distribution of this study as 90% white as the biggest ethnic group of participants, 6.7% black and 3.3% Indian, both as much smaller ethnic groups.

Table 4.3 Ethnic distribution

Ethnicity	Frequency	Percent
White	27	90
Black	2	6.7
Indian	1	3.3

4.3 ANALYSIS OF PRIMARY DATA

To characterize the nature (increase/decrease) of any change in outcomes produced by each intervention, the post-intervention reading was subtracted from the pre-intervention reading. If the pre-post intervention change was calculated as a positive value, then it demonstrated an improvement. If the pre-post intervention change was calculated as a negative value it demonstrated a negative response.

4.3.1 The Comparison of Balance Before and After Cervical Spine Manipulation

As this was a pre-post study design, each participant was their own control and, therefore, the data displays this accordingly. As there was no specific control group, each individual served as a control prior to being exposed to the intervention. The data were collected using the Biodex Biosway® portable balance system as a balance score out of 14, with 14 being the most sway and zero being no sway. **Table 4.4** displays the median and interquartile ranges of balance in the control and intervention. The median is the middle value of the data collected, which was 0.5 for both the control and intervention. What this shows is that there was very little sway of participants both pre and post intervention. The interquartile range shows the spread of data around the median; it can also be the spread of data around each quarter value. This information allows an understanding that with participants who perhaps did have a higher sway index, it was fairly consistent between the pre and post intervention tests. They were noted as the same for the control and intervention groups.

Table 4.4 Balance results

Balance	Median	Percentile 25	Percentile 75
Pre intervention	0.5	0.3	0.7
Post intervention	0.5	0.3	0.7
Change	0.0	0.0	0.0

Table 4.4 displays the results of balance for both the control and intervention. It reveals the maximum sway index for both groups: 3.2 in the control and 2.4 in the intervention group; minimum sway was 0.2 in both groups; the median was 0.5 for both groups. The interquartile range revealed 0.3 for both groups for the 25th percentile and 0.7 for both groups for the 75th percentile. **Figure 4.1** presents the values displayed in **table 4.4** graphically.

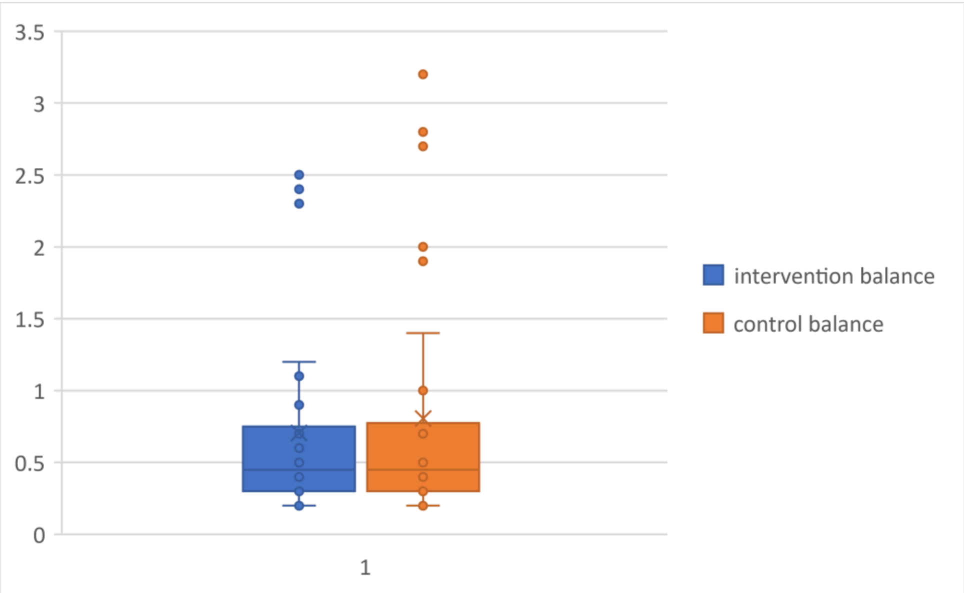

Figure 4.1 Balance

Table 4.5 outlines the hypothesis test summary. Overall, there was no statistically significant difference between the balance of the control and the intervention 'groups', as the significance level was 0.050 and, therefore, the null hypothesis was retained and

asymptotic significance is displayed. This does not however, mean that there were no small changes in balance between the pre and post intervention tests. What is reveals is that any change that was present was not noted as great enough to be significantly relevant with the *p*-value set at 0.050.

Table 4.5 Hypothesis summary balance

Null hypothesis	Test	*p*-value	Decision	Significance level
The median of differences between control balance and intervention balance equals 0.	Related-Samples Wilcoxon Signed Rank Test	0.683	Retain null hypothesis	0.050

Table 4.5 shows that the balance data in this study showed no statistical difference between the intervention and control groups; this is revealed through the fact that the mean values of both the control and the intervention groups was the same. Due to this, it is clear that the difference between these two values is equal to zero. The test used to determine the *p*-value was the Wilcoxon signed rank test. There was no statistical difference between the control and intervention using a paired Wilcoxon signed ranks test (p=0.683). The p=0.683 indicates that, although there is a difference in the data collected between the balance seen in the control and the intervention groups, there is not enough evidence to reject the null hypothesis. For this to occur, the *p*-value would have to be equal or less than 0.05, as this was the chosen value for significance level.

4.3.2 A Comparison of Joint Position Sense Before and After Cervical Spine Manipulation

Joint position sense was tested using the goniometer and was measured in degrees. It was measured as a degree of change, essentially the accuracy of reproduction of a specific degree of flexion of the elbow with visual aid or assistance. It was measured as the difference between actual degree of flexion of the elbow (decided by the researcher), in which the elbow of the participant was placed and the perceived degree of flexion (the attempted reproduction of the previous degree of flexion without aid, by the participant), both pre- and post-cervical spine manipulation. A decrease in error value between pre and post intervention tests, should an improvement in JPS accuracy.

Table 4.6 shows the median and interquartile ranges. As explained, the median is the middle value of the data collected and the interquartile range shows the spread of data around the median but it can also be the spread of data around each quarter value. There was a slight difference between the control and intervention. There was an overall decrease in JPS change in the intervention compared to the control, which indicated an increase in accuracy of JPS with intervention. The decrease in value between the pre-test and the post-test reveals and decrease in JPS error which infers and improvement in JPS accuracy. The individuals were more aware of the position of their elbow after a cervical manipulation of a dysfunctional vertebral joint than they were prior to that manipulation.

Table 4.6 Joint position sense results

JPS	Median	Percentile 25	Percentile 75
Control	10	4	17
Intervention	5	2	12
Change	5	2	5

Table 4.6 displays the results of JPS for both the control and intervention. It reveals the maximum change in JPS in (°) for both groups; 34 in the control and 30 in the intervention group; the minimum change in JPS was zero in both groups, the median was 10 in the control group and five in the intervention group. The interquartile range revealed four for the control and two in the intervention group for the 25th percentile. It also showed 17 for the control groups and 12 for the intervention group for the 75th percentile.

Figure 4.2 presents the values displayed in **table 4.6** graphically.

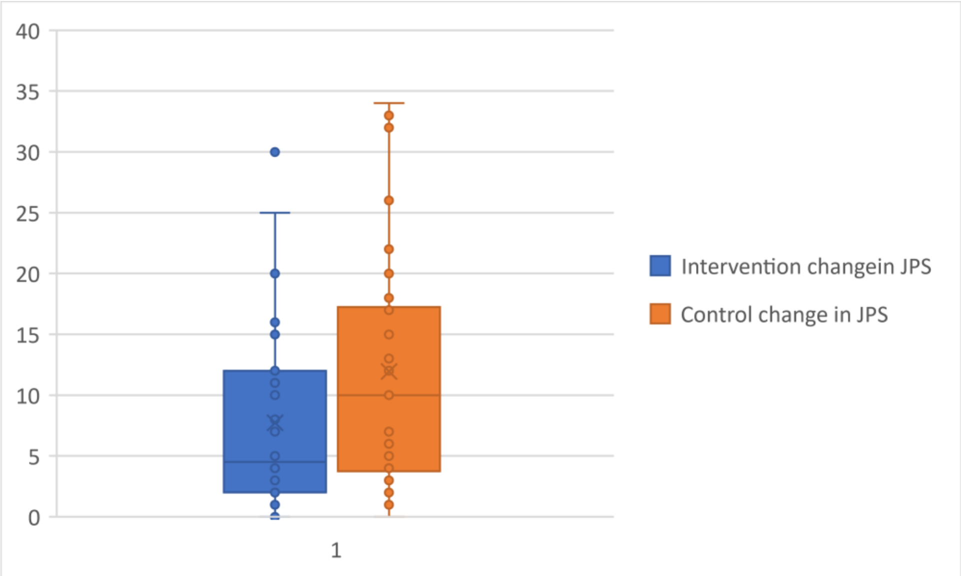

Figure 4.2 Joint position sense

Table 4.7 outlines the hypothesis test summary. There was a clear difference between the change in JPS of the control and the intervention condition.

Table 4.7 Hypothesis summary joint position sense

Null hypothesis	Test	*P*-value	Decision	Significance level
The median of differences between control jps change and intervention jps change equals 0.	Related-Samples Wilcoxon Signed Rank Test	0.032	Reject the null hypothesis	0.050

Table 4.7 displays that the Wilcoxon signed rank test also showed that, statistically, there was a change (*p*=0.032). What this means is that there is enough difference between the control and intervention groups for it to be found statistically significant as the *p*-value is less than 0.05. This allows for the rejection of the null-hypothesis. Asymptotic significance is displayed, meaning that if the sample size were to be enlarged or become “infinite”, the data are estimated to become significant statistically.

4.4 CONCLUSION

The intervention had no statistically significant effect on balance as there was no change found between pre- and post-intervention. However, the intervention was found to decrease the change in JPS significantly from a median of ten to five from before and after the intervention (*p*=0.032). This shows that there was an increase in the accuracy of JPS post intervention.

CHAPTER 5

DISCUSSION OF RESULTS

5.1 INTRODUCTION

This chapter involves the discussion of demographics, as well as the statistical results and data related to the tests conducted on JPS and balance in the elderly. Each variable will be discussed independently in terms of the subjective or objective outcome. Significant correlations between variables will also be discussed.

5.2 DEMOGRAPHICS

5.2.1 Age

Age in this study was an inclusion criterion as this study focused on the elderly. The age of the participants ranged from 61 to 90 years; the mean age was 71.07 years. This was consistent with the United Nations definition of elderly individuals of 60 years and above (Scherbov and Sanderson 2019). This is in keeping with Holt *et al.* (2016), who had a mean age of participants in their study of 72 years.

The data of this study was skewed due to the maximum age being 90 years and an outlier. The data presented for age is therefore misleading as there was only one individual over the age of 80 years. A greater sample size of participants would have allowed for room for a greater diversity of age. It is of particular interest in this study because degeneration continues with age and therefore is greater at an older age, affecting balance and proprioception (Ferlinc *et al.* 2019).

The age of participants in this study was chosen specifically to be over the age of 60 years, due to the high risk of falls in this age group. However, it may be part of the reason that there was no significant change found in balance. Due to the significant degeneration found in the elderly (Eulenburg *et al.*, 2017; Ferlinc *et al.*, 2019), it may be more difficult to detect minor improvements in postural sway after a single chiropractic adjustment. This is due to the fact that there is a decrease in the release of neurotransmitters; slower peripheral nerve impulse conduction, due to degeneration of the myelin sheath around nerves which contributes to slower reflexes; decreased proprioception (Ferlinc *et al.* 2019). These factors may contribute to the minor change in balance, and perhaps warrant more than one adjustment to elicit a clear change in balance. This theory is supported by Holt *et al.* (2016) only noted significant findings between the four to 12 week-period.

5.2.2 Gender

Both males and females participated in this study. There does, however, seem to be evidence to show a difference in falls prevalence and balance between genders. This is in accordance with Morrison *et al.* (2012) who noted that females tend to have a higher prevalence of traumatic falls than men, predominantly due to osteoporosis in menopausal women. Osteoporosisvcan result in muscle weakness, spinal kyphosis and decreased postural control (Meyer, Konig and Hajek 2019). The gender distribution was uniform between the intervention and control in this study, due to the pre-post nature of the study.

This study represented females at 76.7% and males at 23.3%, due to the fact that the sample size of this study not being representative of the general South African population, a parallel between the gender distribution of this study and the gender distribution of the country South Africa, could not be drawn. The misrepresentation of South African gender distribution does not allow this study to clearly represent South Africa's population, even on a small scale, as the demographics did not mimic that of the country.

The inclusion of both genders and higher percentage of female participants, was in accordance with previous studies, such as (Holt *et al.* 2016). The gender distribution was 60% female and 40% male (Holt *et al.* 2016). This study contrasted with Holt *et al.* (2019), which had only male participants.

The larger percentage of female participants may have occurred because the researcher was female and therefore female participants felt more comfortable taking part in the research. This is in accordance with Bertakis *et al.* (2000), who noted in their study that women have higher medical care utilisation than men. Thompson *et al.* (2016) also reiterated this in their study where they found that women visited their health care providers for both physical and mental health issues to a greater extent than men did. Brenton and Elliott (2013) also noted that alternate health care and complimentary alternate health care are viewed as feminine forms of care and therefore women are more prone to go to alternate health care practitioners than men as men tend to be more sceptical. However, the higher percentage of female participants in comparison to male participants did not have any influence on how the intervention affected JPS and balance in the participants. It just made this study less able to reflect the population of the country.

5.2.3 Ethnicity

The ethnic distribution was uniform for the control and intervention, due to the nature of this specific study. The statistical distribution did not accurately represent the ethnic population census of South Africa done in 2011 (Statistic South Africa 2011).

The ethnic differences in balance and prevalence of falls tend to largely depend on where the study is done with regards to each country's ethnic population distribution (Han, Ferris and Baum 2016). It was noticed that in Han, Ferris and Baum's (2016) study that America's falls distribution was 90.7% Caucasian, 4.2% African American, 3.3% Asian, 2.2% Hispanic, and <1.0% Native American, but Hong Kong had a 100% Chinese ethnic fall distribution. There are, however, multiple variables that could affect this outcome of falls prevalence in ethnic groups, such as the ethnic distribution of those countries.

The outcome of a higher percentage of white individuals, could have been due to multiple reasons; the researcher is white, which could have contributed to same race preference in healthcare provider. This is in accordance with Malat and Van Ryn (2005), who showed that one in five Americans preferred same race healthcare providers to healthcare providers of a different race. It is also in accordance with Myburgh and Mouton (2007), who noted that there is a lack of chiropractic exposure in black South Africans. This could be part of the reason for the lack of black participants as there is less understanding of what chiropractic is. This outcome however does not aid in the understanding and exposure of chiropractic to all ethnic groups in South Africa. It did not, however, influence the effect of CSM on balance and JPS.

5.3 ANALYSIS OF PRIMARY DATA

5.3.1 Objective One: To Determine and Compare Pre- and Post-Cervical Spine Manipulation Effect on Balance in Elderly Participants

Balance post-intervention showed no significant difference to balance pre-intervention in this study. The statistical significance level was set at p=0.050 and the data collected on balance produced p=0.683, making it statistically insignificant and, thereby, supporting the null hypothesis. However it is noted that the significance of the p-value does not mean that there was no change in the balance of the participant, rather it shows that although there was change it was not great enough to be noted as statistically significant (Wasserstein and Lazar 2016). The lack of significant change is in accordance with Holt *et al.* (2016), who showed no change in postural sway in elderly individuals after chiropractic care. Holt *et al.* (2016) did, however, show improvements in multiple other variables related to balance, such as choice stepping reaction time and ankle joint position sense post CSM over a 12 week treatment period.

It must be noted that Holt *et al.* (2016) only noted significant findings between the four to 12 week-period. This indicates that perhaps the effect of the CSM may be more relevant over multiple treatments. The decision to retain the null hypothesis outcome was not the expected outcome. This is in contrast to Malaya *et al.* (2020), who revealed that upper and lower limb chiropractic manipulations decreased postural sway and therefore improved postural stability. However, Malaya *et al.* (2020) had participants that were not defined as elderly as their age range was 21 to 40 years, and the intervention group was manipulated twice. Sarker, Sethi and Mohanty (2019) also showed an improvement in postural sway, pain sensitivity and quality of life post SMT and ergonomic advice in comparison with supervised exercise and ergonomic advice. The study noted change over two weeks and four weeks of intervention again, highlighting the impact of multiple treatments.

There are studies that show the effect of SMT on cortical processing which has a strong link to balance and postural control. Haavik, Taylor and Murphy (2007) supported this through the result of their study, which highlighted that CSM of fixated joints can alter somatosensory input and sensorimotor integration. Haavik, Taylor and Murphy (2007) demonstrated this by testing somatosensory evoked potentials of the spinal brain stem and cortical to the median nerve, pre- and post-CSM of a dysfunctional joint segment. The study did not focus on balance itself but rather the effect of CSM on a system that could in turn effect balance and its many related components. Haavik and Murphy (2010) reinforced this as they further highlighted that CSM can alter cortical integration of somatosensory input. Beck (2011) explained that cervical spinal fixations (CSF) can cause altered sensory input in higher processing areas of the brain. This can result in impaired motor output to muscles and joints which are responsible for maintaining balance, JPS and electrical muscular activity (Beck 2011). Neural impulses can be restored through CSM, regarding balance, JPS and electrical activity of muscles.

There are, however, many factors that could have contributed to the lack of change in balance post-intervention in this study. The static balance setting was rather easy for the type of participants who were involved in the study, who seemed to be active, healthy individuals and so standing still on a static surface did not pose as a difficult task. This may have resulted in the pre-intervention balance being good, making it difficult to distinguish a significant change when compared to post-intervention balance. However, this recommendation in in contrast to Holt *et al.* (2016) who showed significant difficulty accomplishing the Biodex Biosway® portable balance system testing on a dynamic surface for individuals over the age of 60 years, this study then reverted to using the test simply as a pass or fail test and therefore the results on balance showed none of the minor changes that could have occurred in individuals. It was for this reason that only static balance was tested in this study, to allow a completion of the test as well as to reduce the risk of injury to the participants. Testing both static and dynamic balance could have resulted in more significant findings as the Biodex Biosway® portable balance system is capable of testing both and it would allow for more data. This would also allow for focus more to be on the response to a changing environment and rapid internal response through balance to maintain an upright posture that is often associated with falls among the elderly. The dynamic testing of balance would shed light onto the effects of balance in everyday life whereby movement it occurring often, the study would then expand more into the concept of kinaesthesia being the ability to perceive not only the position, weight and resistance of objects in relation to the body such as in proprioception, but also includes the perception of the extent, weight and direction of movement (Bernstein and Nash 2008).

The nature of this study being a pre- and post-test study, limited the potential effect of the single CSM could have had on balance over a longer period of treatment time, such as noted in Holt *et al.* (2016) that took place over a 12 week period; Sarker, Sethi and Mohanty (2019) over two weeks; and Lelic *et al.* (2016), that consisted of three sessions of manipulation. Multiple treatments would have allowed for a better outcome and possibly changing the research design to a cross over study may have helped to address this. Another key possibility that could have affected the outcome of this research was the experience or lack thereof, of the researcher as well as the lack of a pilot study.

The researcher in this study had only had approximately two years of clinical experience. This contrasts with Holt *et al.* (2016) who only used chiropractors with 15 years of clinical experience. It is in accordance with other master's research studies that were unpublished but still noted a change in balance post chiropractic manipulation (McKay 2016). The lack of clinical experience effects the ability of the researcher to examine, identify and then accurately treat the fixated spinal segment. This is in accordance with Colloca *et al.* (2020) who revealed training and experience in chiropractic manipulations resulted in shorter thrust times and other important biomechanical variables that have been identified as important factors in the mechanism of chiropractic manipulations and their performance outcomes. This research may have revealed different outcomes had more experienced practitioners administered the manipulations as well as perhaps the use of multiple experienced practitioners being involved.

5.3.2 Objective Two: To Determine and Compare Pre- and Post-Cervical Spine Manipulation Effect on Joint Position Sense in Elderly Participants

The joint position sense was found to improve in participants post-intervention. The joint position sense error values were less in the intervention group than that of the control group. This indicated that the accuracy was better post-intervention. This outcome was in accordance with Fernandez *et al.* (2018), who showed a decrease in JPS error and pain pressure thresholds after CSM. Fernandez *et al.* (2018), however, excluded individuals over the age of 65 years and had multiple practitioners who administered the treatment to the intervention group.

The low significance level of this statistical difference between the control and intervention may be because this was a pre-post study and that it focused on the immediate effect of chiropractic SMT on the JPS and all the participants who were included in this study had undergone the washout period to avoid extra variables that may have affected the data. It is important however, to note that the *p* value does not substitute for scientific reasoning. It cannot be focused on in isolation as a licence to claim a scientific finding. The *p* value is an approach used to summarise incompatibility between a particular set of data and the suggested framework for the data (Wasserstein and Lazar 2016).

Holt *et al.* (2016) had a significant change in JPS after chiropractic management but it was over a 12 week period of weekly treatments and significant change only started to be noticed after the fourth week. This study was a pre- and post-test study to test the immediate effect of CSM on participants. The relevance was, that if a change was noted, it would help the treatment protocol of elderly individuals and prevent unnecessary costs on multiple treatments, provided the outcome supported this treatment protocol.

This study was in accordance with Haavik and Murphy (2011), who demonstrated that elbow JPS improvements were statistically significant post CSM in a pre- post-study design. Haavik and Murphy (2011) used an electro goniometer to test JPS error, and this could have been used in this study to help avoid human error during the use of the manual goniometer. Haavik and Murphy (2011) also highlighted that individuals with subclinical neck pain have significantly worse JPS than individuals without any neck complaints. This is important to note as this study did not use pain as an inclusion or exclusion criteria, and it could have affected the JPS accuracy of individuals. This study would have had more data if pain was noted as a variable or even as a criterion to avoid a lack of consistency as it does affect JPS.

This outcome could support the theory that altered spinal segments/fixations have impaired sensory input in higher processing areas in the brain which affects SMI as the afferent feedback in a fixated spinal segment can alter the feedback from spinal and peripheral nerves (Haavik and Murphy 2012). The SMT of the fixated segments may have improved the dysfunctional sensory input, thus allowing for better SMI, directly effecting JPS and in this case, causing an increase in JPS accuracy (Lelic *et al.* 2016).

Haavik, Taylor and Murphy (2007) demonstrated that individuals suffering from cervical spinal fixations had an altered ability to filter sensory information. This filtering system is important for postural stability (Tinazzi *et al.* 2000). The improvement found in this filtering system after SMT of the fixation may be directly related to postural control and JPS. It has been noted that CSM at higher levels influence the medulla oblongata, as well as the cerebellum, which directly relay proprioceptive information to the upper limb (Cagnie *et al.* 2005). The improvement of JPS could, therefore, be due to the effect upper CSM had on the tracts related to the medulla oblongata according to the proprioceptive insult hypothesis (Gatterman 2005). The lower CSM may have affected elbow JPS due to the neuroanatomical link between the brachial plexus and the cervical spine. It is important to take note that CSM does have an immediate effect on JPS which is a component of balance.

5.4 CONCLUSION

The intervention did not improve participant' balance but augmented their joint position sense.

CHAPTER 6

CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

6.1 CONCLUSION

This study aimed to determine the immediate effect of cervical spine chiropractic manipulative therapy on JPS and sway index as a part of balance in elderly participants in the eThekwini Municipality. The results of this study revealed that CSM of dysfunctional cervical segments does have a positive effect on JPS in the elderly. It was also noted that although CSM does affect balance, it did not have a great enough effect, in this study, for it to be statistically relevant. This study provided a basis for further investigations into the elderly, falls risk and the potential that chiropractic management may have on decreasing the risk of falls among the elderly.

6.2 LIMITATIONS

- This study was limited in that it was designed as a pre- and post-test study single CSM and did not display the possible effect SMT could potentially have on balance in a more extensive study, in which the participants were treated over an extended period. This study was chosen as a pre-post study. The relevance was that if a change was noted, it would help the treatment protocol of elderly individuals and prevent unnecessary costs on multiple treatments, provided the outcome supported this treatment protocol.
- The sample size was also limited to 30 participants, but a larger sample group would have allowed more room for attaining a significant outcome.
- This study was limited to testing static balance, using the Biodex Biosway® portable balance system. A broader set of outcomes would have been noted had dynamic balance also been tested and perhaps multiple methods of testing overall balance which included all three systems.
- Static balance does not reveal the problem reaction of an individual which is necessary for reducing falls risk. This would increase the risk of injury in the study but would provide a clearer outline on the effect of SMT on potential falling.
- The exclusion criteria did not involve the presence of pain; this does not isolate the effect atherogenic muscle inhibition may have on the immediate effect of SMT.

- Concerning human error, although the researcher was made familiar with the procedure and devices being used, human error is often a limitation. A trial run would potentially help decrease the risk of human error, or having multiple researchers performing the same study and comparing data.
- The same individual tested elbow ROM before and after intervention, which increased bias of results of goniometer tests.
- Ethnicity was a limitation in this study as this study did not have an accurate representation of the ethnic distribution of the population of South Africa.
- The gender distribution of this study also caused limitations as there was not an even distribution between male and female participants.
- Individuals with visual impairments or hearing impairments were not isolated from those without. This allowed extra factors that could have contributed to balance impairment other that proprioceptive.
- The vestibular system was not excluded during the JPS test whilst the visual system was, thereby not isolating the proprioceptive aspect of balance completely.

6.3 RECOMMENDATIONS

- Some degrees of flexion were easier to reproduce than others. This pattern may have been a random observation; however, it makes the data less reliable. The effect of using the same degree of flexion both pre- and post-intervention would also affect reliability as it allows for the possibility that repetition influences the ability of the participant to reproduce the degree of flexion. Future studies should perhaps allow the individual to choose a particular comfortable position of flexion and allow this to be the participant's pre-determined degree of flexion, or use a more accurate device to measure JPS, such as an electro goniometer, which could have avoided some human error.
- Various tests for balance, such as static and dynamic balance and stand and reach tests, should also be incorporated so that a more comprehensive assessment of balance can be done.
- Dynamic balance can also be done in conjunction with static, this will allow for further data on the effect of the SMT on balance in daily life. May allow for a better depiction of improvements in balance if the test is slightly more difficult.
- A crossover design should be used for further studies of this nature, as the participants can be their own control and some bias can be eliminated.

- A study may examine participants over an extended period of perhaps four weeks as this seems to be when most statistically relevant changes are noticed. This may be more beneficial.
- The implementation of a pilot study is essential to reduce researcher error.
- The measure of intra-tester reliability is essential for elbow goniometry.
- The measure of inter-tester reliability is essential for elbow goniometry.
- The recruitment of a larger sample size.
- The use of body mass index and stature to be added as variable in data collection.

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APPENDICES

Appendix A: (063/21) Institutional Research Ethical Committee (IREC) permission

DUT
DURBAN UNIVERSITY OF TECHNOLOGY
INYUVESI YASETHEKWINI YEZOBUCHWEPHESHE

INSTITUTIONAL RESEARCH ETHICS COMMITTEE

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

7 July 2021

Ms R D Bonsma
P O Box 159
Underberg
3257

Dear Ms Bonsma

The immediate effect of chiropractic cervical manipulative therapy on joint position sense and balance in elderly participants in the eThekwini Municipality
Ethics Clearance Number: IREC 063/21

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

Prof J K Adam
Chairperson: IREC

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THE WORLD UNIVERSITY RANKINGS 2021 TOP 500

Appendix B: Permission from the Owner of the Chiropractic Practice to Use a Room at the Off-Campus Practice Room for Research Purposes

DR. CLEO PRINCE

Registered Chiropractor
MTech: Chiropractic
Registration no. A11619
Practice no. 0589659

Suite 109 , Musgrave Park
18 Musgrave Road
Musgrave
Durban
4001
Tel: 0312202190
Cel: 0617991405

To : Prof Adam
Chair: IREC

From : Dr Cleo Prince
Registered Chiropractic Practitioner (A11619) and Lecturer - Department of Chiropractic, Durban University of Technology

Date : 03.06.2021

Re : Request for permission to use my private practice location as a data collection site

Permission is hereby granted to:

Ms Robyn Bonsma (Student Number: 21518899)

Research title: "The immediate effect of cervical spine manipulation on balance and joint position sense in elderly participants in the eThekwini Municipality".

To make us of my private practice located at Suite 109, Musgrave Park, 18 Musgrave Road , as a data collection site. I will be the clinician on duty to sign off any clinical paperwork.

Thank you for your time.

Kind regards

Dr C Prince
Registered Chiropractic Practitioner
Lecturer: Department of Chiropractic, DUT

Appendix C: Permission to Conduct Research from the Clinic Director at the DUT Chiropractic Day Clinic

MEMORANDUM

To	:	Prof Adam Chair: IREC
From	:	Dr Desiree Varatharajullu Head of Department: Chiropractic Clinic Director: Chiropractic Day Clinic: Chiropractic
Date	:	02.06.2021
Re	:	Request for permission to use the Chiropractic Day Clinic for research purposes

Permission is hereby granted to:

Ms Robyn Bonsma (Student Number: 21518899)

Research title: "The immediate effect of cervical spine manipulation on balance and joint position sense in elderly participants in the eThekwini Municipality".

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

Thank you for your time.

Kind regards

Dr D Varatharajullu

Head of Department: Chiropractic

Clinic Director: Chiropractic Day Clinic: Chiropractic

Cc: Mrs Linda Twiggs: Chiropractic Day Clinic

Dr P. Maharaj: Supervisor

Dr C. Korporaal: Co-supervisor

Appendix D: Permission to Conduct Research from the Research Director at the DUT

DUT DURBAN UNIVERSITY OF TECHNOLOGY

DIRECTORATE FOR RESEARCH AND POSTGRADUATE SUPPORT

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

17th June 2021
Ms Robyn Bonsma
c/o Department of Chiropractic and Somatology
Faculty of Health Sciences
Durban University of Technology

Dear Ms Bonsma

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 **Gatekeeper Permission** for you to conduct your research "The immediate effect of chiropractic cervical spinal manipulative therapy on joint position sense and balance in elderly participants in the eThekwini Municipality" at the Durban University of Technology. **Kindly note that this letter must be issued to the IREC for approval before you commence data collection.**

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 would 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 E1: Advertisement (English)

DUT

DURBAN UNIVERSITY OF TECHNOLOGY

INYUVESI YASETHEKWINI YEZOBUCHWEPHESHE

Faculty of Health Sciences

CHIROPRACTIC

CALLING ALL AGES 60 AND ABOVE

Do **you** want to be part of an interesting **Study?**
You could receive a free chiropractic
neck assessment **and** treatment!

Call Robyn: 083555 75 41

Or the DUT Chiropractic Day Clinic: 0313732511

Call to see if you qualify to be part of this
exciting study that explores **balance** and **joints**

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THE WORLD UNIVERSITY RANKINGS 2021 TOP 500

DUT - RANKED IN THE TOP 5 OF ALL SOUTH AFRICAN UNIVERSITIES

Appendix E2: Advertisement (isiZulu)

DUT

DURBAN UNIVERSITY OF TECHNOLOGY

INYUVESI YASETHEKWINI YEZOBUCHWEPHESHE

Faculty of Health Sciences

CHIROPRACTIC

Kungabe uyathanda ukuba ingxenye yocwaningo oluhlaba umxhwele?? Ungase uzibeke ethubeni ngokuhlolwa nokwelashwa mahhala komqala ngendlela yakwa-Chiropractic!

Shayela u-Robyn: 083 555 75 41

Noma

Emtholampilo wakwa-chiropractic ose Nyuvesi YaseThekwini Yezobuchwepheshe i: ku- 031 373 2511 uyacelwa ukuba ushaye uzwe uma ungaba ingxenye yalolucwaningo oluhlaba umxhwele ngokubhekisisa ibhalansi kanye namalungu omqala.

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fairness • professionalism • commitment • compassion • excellence

THE WORLD UNIVERSITY RANKINGS 2021 TOP 500

DUT - RANKED IN THE TOP 5 OF ALL SOUTH AFRICAN UNIVERSITIES

Appendix F: Permission to Place Advertisement

[Date]

Request for Permission to Place Advertisements

Dear Sir/Madam

My name is Robyn Bonsma, an M.Tech: Chiropractic student at the Durban University of Technology. The research I wish to conduct for my master's dissertation involves "The immediate effect of cervical spine manipulation on joint position sense and balance in elderly participants in the eThekwini Municipality".

I am hereby seeking your consent to place an advertisement, which is attached, on your premises to recruit participants for my research.

I have provided you with a copy of my proposal which includes copies of the data collection tools and consent and/ or assent forms to be used in the research process, as well as a copy of the approval letter which I received from the Institutional Research Ethics Committee (IREC).

If you require any further information, please do not hesitate to contact me 0835557541 or robyn.bonsma@gmail.com . Thank you for your time and consideration in this matter.

Yours sincerely,

Robyn Bonsma

Durban University of Technology

Appendix G1: Telephonic Screening Table (English)

Questions asked to prospective participants	Expected Answers	Actual Answers
Participant's Code: e.g. X		
Please may I ask you some questions?	Yes	
Are you 60 years or older?	Yes	
Have you had any surgery to the neck or head in the last 3 months	No	
Are you wheelchair bound	No	
Have you had any cervical SMT in the last 4 weeks	No	
To the best of your knowledge, do you suffer from any of the following; atherosclerosis, vertebrobasilar insufficiency, aneurysm, tumours, fractures, severe sprains, late stage osteoarthritis, clotting disorders, osteopenia, space occupying lesions, diabetic neuropathy, malingering, hysteria, hypochondriasis and Alzheimer's disease?	No	
Do you suffer from hypertension, have a history of trauma to the head or neck or recent surgery within three months to the head or neck?	No	
Can you remain standing unassisted for one minute?	Yes	
Do you, to the best of your knowledge suffer from balance impairment due to Meniere's disease, ear infections, hypotension, blurred vision, vertigo?	No	

Appendix G2: Telephonic Screening Table (isiZulu)

Ikhodi yombambiqhaza: **isb. X**		
Imibuzo ebuzwe kubabambiqhaza	**Izimpendulo ezilindelekile**	**Izimpendulo Okuyizo**
Ngingakubuza imibuzo elandelayo?	Yebo	
Kungabe uphezu kweminyaka engu-60?	Yebo	
Kungabe usebenzisa isihlalo samasondo	Cha	
Ngabe uke wathola ukwelulwa komqala emasontweni amane edlule	Cha	
Ngoko lwazi onalo, kungabe kukhona ukukuphathayo kuloku okulandelayo; ukuqina kwemithambo yegazi, i-vertebrobasilar insufficiency,i-anuerysm, izimila, ukuphuka, ukwenyela, isifo samathambo, ukuvaleka kwemithambo yegazi, i-osteopenia, i-space occupying lesions, i- diabetic neuropathy, i-i-malingering, i-hysteria, i-hypochondriasis kanye nesifo se-Alzeheimer's.	Cha	
Kungabe unenkinga yomfutho wegazi ophezulu, umlando wokulimala ekhanda noma emqaleni noma ukuhlinzwa ezinyangeni ezintathu ekhanda noma emqaleni?	Cha	
Uyakwazi ukuzimela umzuzu owodwa ngale kokusizwa?	Yebo	
Kungabe, ngolwazi onalo unako ukuphazamiseka kwe-bhalansi ngenxa yesifo i-Meniere's, isifo sendlebe, umfutho wegazi ophansi, ukungaboni kahle, isiyezi?	Cha	

Appendix H1: CDC Entry English

COVID-19

Declaration for entry into the Chiropractic Day Clinic

Name: ________________________________

Surname: ______________________________

Participant's code: ______

Contact number: ________________________

Reason for entry: **Research Participant**

Body temperature reading at time of entry: _________

Tick as applicable:	YES	NO
Have you been in contact in the last 14 days with someone who is confirmed to have COVID-19?		
Are you currently suffering with any of the following symptoms?		
Cough		
Fever		
Sore throat		
Shortness of breath (or difficulty breathing)		
Fatigue, weakness or tiredness		
Aches and pains or headaches		
Loss of smell		
Loss of taste		
Redness of eyes		
Nausea		
Vomiting		
Diarrhoea		

Declaration
I hereby declare that the information I have disclosed is correct at the time of completion.

Signature: ___________________

Date: ______________________

Appendix H2: CDC Entry isiZulu

COVID-19

Isifungo sokungena emtholampilo we-Chiropractic

Igama: ______________________

Isibongo: _______________________________

Nombolo ye-fayili: _______

Ucingo: _________________________

Isizathu sokubamba iqhaza: **Research Participant**

Izinga lokushisa komzimba ngesikhathi sokubamba iqhaza: _________

Beka umaka kokufanelekile:	**YEBO**	**CHA**
Uke wasondelana nomuntu oqinisekiwe ngokuba negciwane i-COVID-19?		
Kungabe kukhona izimpawu zokugula onazo kulezi ezilandelayo?		
Ukukhohlela		
Imfiva		
Umphimbo obuhlungu		
Ukuphelelwa umoya (noma ukuphefumula kanzima)		
Ukubhocobala, Ubuthaka noma ukukhathala		
Ukunkenketha nobuhlungu bekhanda		
Ukulahlekelwa iphunga		
Ukulahlekelwa ukunambitha		
Ukuba bovu kwamehlo		
Nhliziyo encani		
Ukuphalaza		
Isifo sohudo		

Isifungo
Ngalokhu ngiyafunga ukuthi imininingwane engiyidalulile ngesikhathi ngiqeda ukushicilela iyiqiniso.

Isiginisha: ________________________

Usuku: ___________________________

Appendix I1: COVID-19 Consent Form (English)

CONSENT FOR CHIROPRACTIC TREATMENT DURING THE COVID-19 PANDEMIC

I, ______________________________knowingly and willingly consent for myself to participate in elective Chiropractic treatment from a Durban University of Technology Chiropractic masters student for research purposes during the COVID-19 pandemic.

I understand the COVID-19 virus has a long incubation period during which carriers of the virus may not show symptoms but still be highly contagious.

Chiropractic procedures/treatments take place with the patient in very close proximity to the practitioner. This potentially exposes the patient and the practitioner to the COVID-19 virus. I understand that due to the frequency of other Chiropractic patients, the characteristics of the virus, and the characteristics of Chiropractic practice, that I have an elevated risk of contracting the virus simply by being in the Chiropractic clinic.___(initial)

I Confirm that I am not presenting with ANY of the following symptoms of COVID-19 listed below:

- **Fever**
- **Shortness of breath**
- **Dry cough**
- **Runny nose**
- **Sore throat**

High risk patient relating to the severity of COVID-19 are persons of/over the age of 60 and persons who have pre-existing medical conditions such as: asthma, chronic lung conditions, hypertension, autoimmune diseases, organ transplants, cancer, immunocompromised, obesity (BMI over 40), more than 27 weeks pregnant and liver or kidney conditions.

I confirm that I do fall into these high health risk categories and I am aware of the increase risk of severe infection due to my age/pre-existing medical conditions should I contract COVID-19____(initial)

I am aware of the risks involved with the spread of COVID-19 and the risks it may hold to my health and the health of the others I come into contact with. I accept those risks and hereby indemnify and hold the Durban University of Technology Chiropractic Day Clinic and its students and staff blameless should I contract the disease during my participation in this research trial.

Participant's signature DATE

Researcher's signature

Clinician's signature

Appendix I2: COVID-19 Consent Form (isiZulu)

ISIVUMELWANO SOKWELASHWA NGOKWE-CHIROPRACTIC NGESIKHATHI SOBHUBHANE I-COVID-19

Mina,______________________ngokwazi nangokuthanda ngiyazibophezela ekubambeni iqhaza lokwelashwa ngokukhethekile ngendlela yakwa-Chiropractic ngumfundi we-masters owenza ucwaningo eNyuvesi yaseThekwini Yezobuchwepheshe ngesikhathi sokubheduka kobhubhane i-COVID-19 .

Ngiyiqonda ukuthi igciwane le-COVID-19 lineskhathi eside sokufukameleka, okungenza abantu abalithwele bangabi nazimpawu kodwa bekwazi ukulidlulisela kwabanye.

Izinqubo/ukwelashwa ngokwe-Chiropractic kwenzeka ngendlela yokuthi isiguli mele sisondelane kakhulu nodokodetela. Lokhu kungase kubeke isiguli kanye nodokotela engcupheni ye-COVID-19. Ngiyaqonda ukuthi ngenxa yokuvama kwezinye zeziguli zakwa-chiropractic, nezici zegciwane, kanye nesimo segumbi lokusebenzela le-chiropractic, nginezinga eliphakeme lobungozi bokuthola igciwane ngokuba semtholampilo wakwa-chiropractic._(iziqalo zamagama)

Ngiyaqinisekisa ukuthi anginazo izimpawu ezilandelayo ze-COVID-19 ezibhalwe ngezansi:

- **Imfiva**
- **Ukuphelelwa umoya**
- **Ukukhohlela okomile**
- **Impumulo evuzayo**
- **Umphimbo obuhlungu**

Iziguli ezazeka ngokuthi zisengcupheni enkulu ye-COVID-19 abantu beminyaka/abangaphezulu kweminyaka engama-60 kanye nabantu abanezifo ezingomahlalekhona okunjenge: isifuba somoya, izifo zamaphaphu, umfutho wegazi ophezulu, izifo zamasosha omzimba, ukufakelwa kwezicubu zomzimba, umdlavuza, ukucindizeleka kwamasosha omzimba, ukukhuluphala ngokweqile (BMI engaphezu kwama-40), nongaphezulu kwama-27 ezithwele kanye nezifo zesbindi noma zezinso.

Ngiyazi ukuthi ngingaphansi kwabantu abasezingeni eliphezulu lengcuphe yokutheleleka futhi ngiyazi ngokunyuka kwengcuphe yokutheleleka ngegciwane ngenxa yeminyaka yami/ nezifo ezikhona emzimbeni uma kungenzeka ngitheleleke.

I-COVID-19___(Iziqalo zamagama)

Ngiyazi ngobungozi obuphathelene nokubhebhetheka kwe-gciwane le-COVID-19 futhi ubungozi kungathinta impilo yami nalabo engisondelene nabo. Ngiyakwamukela lobo bungozi futhi ngiyaqinisekisa ukuthi angeke ngisole abafundi kanye nomtholampilo we-Chiropractic oseNyuvesi yaseThekwini Yezobuchwepheshe uma kungase ngitheleleke ngesifo ngesikhathi sokuzibandakanya kwami kulolu cwaningo.

Isiginisha yombambiqhaza

USUKU

Isiginisha yomcwaningi

Isiginisha kadokotela

Appendix J1: Permission to Use the BBPBS Off Campus (HoD)

17 February 17, 2020

Dr. Desiree Varatharajullu

Head of Department: Chiropractic

<u>Request for Permission to Utilize Portable Durban University of Technology Equipment Off Campus for Research</u>

Dear Dr. L. O'Connor

My name is Robyn Bonsma, an MTech: Chiropractic student at the Durban University of Technology. The research I wish to conduct for my master's dissertation involves "The immediate effect of cervical spine manipulation on balance and joint position sense in elderly participants in the eThekwini Municipality".

I am hereby seeking your consent to access and utilization of the Biodex Biosway Portable Balance System off campus grounds.

I have provided you with a copy of my proposal which includes copies of the data collection tools and consent and/ or assent forms to be used in the research process.

If you require any further information, please do not hesitate to contact me (0835557541) Thank you for your time and consideration in this matter.

Yours sincerely,

Robyn Bonsma

Durban University of Technology

Appendix J2: Permission to Use the BBPBS Off-Campus (Assets Control Clerk)

17 February 17, 2020

Mr V. Nair

Asset Control Clerk

<u>Request for Permission to Utilize Portable Durban University of Technology Equipment Off Campus for Research</u>

Dear Mr V. Nair

My name is Robyn Bonsma, an MTech: Chiropractic student at the Durban University of Technology. The research I wish to conduct for my master's dissertation involves "The immediate effect of cervical spine manipulation on balance and joint position sense in elderly participants in the eThekwini Municipality".

I am hereby seeking your consent to access and utilization of the Biodex Biosway Portable Balance System off campus grounds.

I have provided you with a copy of my proposal which includes copies of the data collection tools and consent and/ or assent forms to be used in the research process.

If you require any further information, please do not hesitate to contact me (0835557541) Thank you for your time and consideration in this matter.

Yours sincerely,

Robyn Bonsma

Durban University of Technolog

Appendix K1: Letter of Information English

LETTER OF INFORMATION

Dear participant,

Title of the Research Study: The immediate effect of cervical spine manipulation on balance and joint position sense in elderly participants in the eThekwini Municipality.

Principal Investigator/s/researcher: Robyn Bonsma [B.Tech: Chiropractic]

Supervisor: Dr. D. Varatharajullu [M.Tech: Chiropractic]

Co-supervisor: Dr. C. Prince [M.Tech: Chiropractic]

Brief Introduction and Purpose of the Study:

As one gets older so your balance starts to get worse, which makes the risk of falling much higher. Falling has many negative effects on a person and healing also tends to be a slower process. It is very important to try and avoid falling and the injuries that often go with it, especially as one gets older. There are numerous causes of falls and because of this, many different ways in which to try to avoid falling or at least decrease ones' risk of falling. Chiropractic adjustments have been known to improve balance in the elderly as well as other important factors which are involved in balance, such as joint position sense, which is your body's understanding of where each joint is. The purpose of this study is to see how Chiropractic adjustments of the neck affect balance and joint position sense in the elderly to see if it can be used to decrease ones' risk of falling and therefore prevent some fall related injuries. Specifically, in South Africa where there is limited research on a study of this kind and so many elderly people who fall are unable to get the care that they need.

Good Day,

Introduction; I am a 5th year DUT student currently completing my masters research in Chiropractic.

Invitation: I would like to invite you to participate in my research.

What is Research: research is a systematic search or enquiry for generalized new knowledge.

Outline of the Procedures:

After a simple phone screening to determine if you meet the inclusion criteria, an appointment will be made for you at the chiropractic practice being used for this study.

A full case history of your past and current medical experiences as well as a physical examination to assess your current health will be done, then a focused assessment of your neck will be done.

You will then be asked to stand on two feet for 20seconds on a machine which measures how well you can balance and your balance will be measured and noted.

Then you be asked to close your eyes, the elbow of your dominant arm will be put into a slightly bent position and you will be asked to remember that position as best as possible. Your elbow will be straightened and you will be asked to bend your arm to the position it was put in as best as you can. Both of these angles will be measured and noted. Thereafter, manipulation will be administered to a joint in your neck which is the most restricted or is the farthest from its best possible movement, using a quick adjustment movement that uses very little force.

Measurements of balance and elbow position sense will be retaken.

Risks or Discomforts to the Participant: it is important to be aware of any risks you could suffer from, whilst participating in this research study. Although it's unlikely, you can suffer from transient muscle pain after the adjustment, Vertebral Artery Infarction/ Stroke, Vertebral artery dissemination or mild headaches.

Reason/s why the Participant May Be Withdrawn from the Study: If you suffer any adverse reactions and wish to withdraw from the study, you are free to do so. These adverse reactions if treatable by a chiropractor they will be referred to the DUT Clinic for treatment. If they are out of scope of practice of a Chiropractor, a referral letter will be given to seek other medical advice; however, you will be held liable financially for any other medical care. Due to the nature of this study if you are found to be uncompliant with the procedures required, you will have to be removed from the study. You are free to withdraw from the study at any time. Withdrawal will not prevent you from receiving further treatment at the Chiropractic Day Clinic at normal clinic rates.

Benefits: Being involved in this study could potentially have positive effects on your balance and awareness of where each of your joints are and control over their specific movements as well as increased movement in your neck. You will play a part in the development and understanding of Chiropractic treatment in the elderly and its effect on factors affecting falls risk that could aid in future treatment of such things in the future. You will also receive a free physical examination.

Remuneration: There will be no form of remuneration offered to you for taking part in the study.

Costs of the Study: You will not be expected to contribute to any costs of the study.

Confidentiality: All your medical records will be kept confidential and will be stored in the Chiropractic Day Clinic. The hard copy data will be stored at the Chiropractic department and raw electronic data will be stored on a USB at DUT. After five years, the hard copies will be shredded and the electronic data will be deleted**.** Your name will not appear on any of the data sheets or thesis.

Results:

Research-related Injury: There are no foreseeable injuries occurring with this study. Compensation in the event of an injury is not possible, however free treatment for the injury can be arranged with an intern at the Durban University of Technology Chiropractic Day Clinic provided the injury is within chiropractic scope of practice. If not the patient will be given a referral for alternate medical care.

Storage of all electronic and hard copies including tape recordings:

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

Dr Desiree Varatharajullu: desireev@dut.ac.za or Dr Cleo Prince: cleop@dut.ac.za

Please contact the researcher (083 555 75 41)

My supervisor (031 373 2533) or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Director: Research and Postgraduate Support, Prof S Moyo on 031 373 2577 or moyos@dut.ac.za

Appendix K2: Letter of Information isiZulu

INCWADI YOLWAZI

Mbambiqhaza othandekayo

Ngiyakwamukela kucwaningo lwani. Ngyabonga ngokuhlanganyela kwakho.

Isihloko socwaningo: Umthelela wokwelulwa komqala kwi-bhalansi kanye nesimo sokuma kwamalungu ebantwini asebekhulile.

Umphenyi omkhulu/ umcwaningi: Robyn Bonsma [B.Tech: Chiropractic]

Umphathi: Dkt. D. Varatharajullu [M.Tech: Chiropractic]

Umlekeleli womphathi: Dkt. C. Prince [M.Tech: Chiropractic]

Isingeniso bufuphi kanye nenhloso yocwaningo:

Uma umuntu ekhula izinga lebhalansi liyaqala ukwehla, okuholela ekutheni ube sengcupheni ephezulu yokuwa. Ukuwa kunomthethela omubi kumuntu futhi kuvama ukwehlisa izinga lokululama. Kubaluleke kakhulu ukuzama uphinde ugweme ukuwa kanye nezingozi eziphathelene nokuwa, ikakhulukazi uma umuntu eseba mudala. Ziningi izinto ezingaba imbangela yokuwa nakanjalo ziningi izindlela ekungazanywa kuphinde kugwenywe ukuwa noma kuhliswe ingcuphe yokuwa. Ukwelulwa ngendlela yakwa-chiropractic kwazeka ngokuthi kusimamisa ibhalansi ebantwini asebekhulile kanye nezinye izici ezibalulekile eziphathelene nebhalansi njenge muzwa wokuma kwamalungu okuyindlela yokuqonda komzimba yokuthi likuphi ilungu lozimba ngalinye. Inhloso yocwaningo ukuthola umthelela yokwelulwa komqala ngendlela yakwa-chiropractic kwi-bhalansi kanye nomuzwa wokuma kwamalungu ebantwini asebekhulile, phinde kubhekwe ukuthi ingasetshenziselwa ukunciphisa ingcuphe yokuwa ngalokho igweme izingozi eziphathelene nokuwa. Ikakhulukazi eNinguzimu Afrika lapho uhlobo lalolu cwaningo lungakaze lwenziwe kuphinde kubenabantu asebekhulile abavama ukuwa baphinde bangakutholi ukunakekeleka abakudingayo.

Umhlahlandlela wenqubo mgomo:

Emuva kokuhlolisisa ngokufona ukuze kwazeke uma ungaba yingxenye yocwaningo, kuzobe sekubekwa isikhathi sokuza ezindlini zokwelapha ezizobe zisetshenziselwa ucwaningo. Isimo sakho sempilo sakamuva nesamanje sizobe sesihlolisiswa ngokuthi ubuzwe uhla lwemibuzo ephathelene nesimo sempilo futhi uzophinde uxilongwe ukuze kubhekwe isimo sakho sempilo samanje, bese kubhekisiswa kuhlolisiswe isimo somqala wakho. Uzobe usuyacelwa ukuba ume ngezinyawo zakho zombili imizuzwana engama-30 emshinini okala isimo sakho sebhalansi kuzobe sekukalwa ibhalansi yakho bese iqoshwe phansi.

Okulandelayo uzobe usuyacelwa ukuba uvale amehlo, kuzobe segugotshiswa kancane indololwane yengalo yakho yokwesokunene bese uzocelwa ukuba ukhumbulisise kahle indlela ade ingalo yakho imiswe ngayo. Kuzobe sekwelulwa indololwane yakho bese ucelwe ugobise ingalo ngendlela ade igotshiswe ngayo phambilini. Womabili ama-engela azobe eseyakalwa aphinde aqoshwe phansi. Okulandelayo, kuyobe sekululwa amalungu omqala avimbezelekile noma anganyakazi ngendlela ekhululekile okumele anyakaze ngayo, lapho okuzobe kusetshenziswa ukwelulwa okusheshayo okusebenzisa amandla amancinyane. Izikalo zebhalansi kanye nesimo sokuma kwendololwane sizobe ziyathathwa futhi.

Ubungozi noma ukungakhululeki kumbambiqhaza:

Inzuzo:

Ukuzibandakwanya kwakho kulolu cwaningo kungakusiza ekuzuzeni imiphumela emihle kwi-bhalansi yakho phinde uqwashiseke ngesimo samalungu akho omzimba kanye nokwazi ukulawula ukunyakaza okuthize kanye nokunyakaza ngokweqile komqala wakho. Uzobe usuphinde udlala ingxenye ekuthuthukiseni kanye nasekuqondisiseni kokwelashwa kwabantu asebekhulile nge-chiropractic kanye nemiphumela ezicini eziphathelene nokuwa okungaphinde kusize ekulapheni izinto ezifana nalezi kusasa.

Izizathu/Isizathu esingaholela ekutheni umbambiqhaza ahoxe kucwaningo:

Uma kwenzeka kuba khona ubungozi ongahlangabezana nabo futhi ufuna ukuhoxa kucwaningo, wamulekile ukwenza njalo. Uma ubungozi bungalashwa ngu-Dokotela wamathambo uzobe usudluliselwa emtholampilo waseNyuvesi YaseThekwini Yezobuchwepheshe ukuze uthole ukwelashwa. Uma ukwelashwa kungekho ngaphansi kwa-dokotela wamathambo, kuzobe sekukhishwa incwadi egunyaza ukufuna okunye ukwelulekwa ngokwezempilo. Noma kunjalo, uzobe usubophezeleka ngokwezezimali eziphathelene nokwezokulashwa. Mayelana nesimo socwaningo uma utholakala ungenako ukuvumelana nezinqubomgomo ezidingekayo, uzobe usuyacelwa ukuba uhoxe kucwaningo. Uvumelekile ukuhoxa kulolu cwaningo nanoma ingasiphi isikhathi. Ukuhoxa angeke kuvimbe ukuthola ukwelashwa emtholampilo wakwa-chiropractic ngamanani ajwayelekile asemtholampilo.

Isinxephezelo: Angeke kube khona uhlobo oluthize lesinxephezelo ozosithola ngokuzibandakanya kwakho kulolu cwaningo.

Izindleko zocwaningo: Awulindelekile ukuba ufake isandla ezindlekweni zalolu cwaningo.

Ubumfihlo: Yonke imininingwane yakho yezempilo izogcinwa iyimfihlo izophinde igcinwe emtholampilo wakwa-chiropractic. Ikhophi ethintekayo izogcinwa emnyangweni yakwa-chiropractic bese ulwazi olungahluziwe logesi lizogcinwa kwi-USB eNyuvesi YaseThekwini Yezobuchwepheshe. Emuva kweminyaka eyishlanu, amakhophi athintekayo azobe eseyaklebhulwa bese ulwazi olugcinwe ngokogesi luyasuwsa. Igama lakho angeke livele kunoma eliphi iphepha eliqukethe ulwazi noma embhalweni onobuhlakani wokuthola iziqu enyuvesi.

Ubungozi obuhlobene nocwaningo: abukho ubungozi obuhlonene nocwaningo okubonakala kungenzeka. Asikho isinxephezelo uma kungenzeka wehlelwe ingozi ngesikhathi socwaningo, kodwa kungahlelwa ukuthi uthole ukwelashwa mahhala ngumfundi emtholampilo wakwa-chiropractic oseNyuvesi yaseThekwini Yezobuchwepheshe uma ingozi yazeka ukuthi ilapheke ngendlela yakwa-chiropractic. Uma kungenjalo isiguli sizobe sesinikwa incwadi yokudluliselwa komunye umhlinzeki wezempilo.

Abantu ongaxhumana nabo uma kunezinkinga noma imibuzo:

Dkt. Desiree Varatharajullu: desireev@dut.ac.za noma Dkt. Cleo Prince: cleop2dut.ac.za

Uyacelwa ukuba uxhumane nomcwaningi ku (083 555 7541)

Umphathi wami (031 373 2533) noma Umlawuli weZimiso Zokuhlelwa kweZocwaningo weSikhungo ku 031 373 2375.

Izikhalazo zingadluliswa ku Mqondisi: Ucwaningo kanye nokwesekwa kwaba neziqu, Solwazi S Moyo ku 031 373 2577 or moyos@dut.ac.za

Appendix L1: Letter of Informed Consent (English)

<u>**CONSENT**</u>

Title of the Research Study: The immediate effect of cervical spine manipulation on balance and joint position sense in elderly participants in the eThekwini Municipality.

Principal Investigator/s/researcher: Robyn Bonsma [B.Tech: Chiropractic]

Supervisor: Dr. D. Varatharajullu [M.Tech: Chiropractic]

Co-supervisor: Dr. C. Prince [M.Tech: Chiropractic]

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, Robyn Bonsma, about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: ______.
- 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/ Right Thumbprint**

I, <u>Robyn Bonsma</u> herewith confirm that the above participant has been fully informed about the conduct, nature and risks of the above study.

Robyn Bonsma

______________________ ____________ ______________________

Full Name of Researcher **Date** **Signature**

______________________ ____________ ______________________

Full Name of Witness (If applicable) **Date** **Signature**

______________________ ____________ ______________________

Full Name of Legal Guardian (If applicable) **Date** **Signature**

Appendix L2: Letter of Informed Consent (isiZulu)

<u>**Imvume**</u>

Isihloko socwaningo: Umthelela wokwelulwa komqala kwi-bhalansi kanye nesimo sokuma kwamalungu ebantwini asebekhulile.

Umphenyi omkhulu/ umcwaningi: Robyn Bonsma [B.Tech: Chiropractic]

Umphathi: Dkt. D. Varatharajullu [M.Tech: Chiropractic]

Umlekeleli womphathi: Dkt. C. Prince [M.Tech: Chiropractic]

Istatimende sesivumelwano sokubamba iqhaza kucwaningo:

- Ngiyaqinisekisa ukuthi ngazisiwe ngumcwaningi, Robyn Bonsma, ngesimo, inqubo, inzuzo kanye nobungozi bocwaningo- Inombolo yocwaningo: _________
- Ngiphinde nganikezwa, ngafunda futhi ngaqondisisa ulwazi olubhaliwe ngaphezulu (incwadi yolwazi) mayelana nocwaningo.
- Ngiyazi ukuthi imiphumela yalolu cwaningo, kanye nemininingwane yami ephathelene nobulili bami, iminyaka, usuku lokuzalwa, amagama ami kanye nesimo sempilo yami sizogcinwa siyimfihlo mesekufika isikhathi sokwethulwa kolwazi.
- Ekubhekeni izimfuno zocwaningo, ngiyavuma ukuthi ulwazi oluqoqwe ngesikhathi socwaningo lunga shicilelwa kwi-computer ngumcwaningi.
- Noma kwesiphi isigaba socwaningo, ngaphandle kokulimala, ngingahoxisa ukuzibandakanya kwami kucwaningo.
- Ngibe nethuba elanele lokubuza imibuzo kanye (ngokufisa kwami) ngalokhu ngiyaqinisekisa ukuthi ngikulungele ukubamba iqhaza kucwaningo.
- Ngiyaqonda ukuthi imiphumela emisha nesemqoka ethuthukiswe ngesikhathi socwaningo engaphathalana nokubamba iqhaza kucwaningo igenziwa ukuthi itholakale mengiydinga.

______________________	______________	_________	_____________________
Igama lombambiqhaza	**Usuku**	**Isikhathi**	**Isiginisha/Isithupha**

Mina, <u>Robyn Bonsma</u> ngiyaqinisekisa ukuthi umbambiqhaza wazisiwe ngokugcwele ngenqubo, nemvelo kanye nobungozi obubhathelene nocwaningo.

Robyn Bonsma

________________________	_____________	_______________________
Igama lomcwaningi	**Usuku**	**Isiginisha**
________________________	_____________	_______________________
Igama lofakazi (uma kufanelekile)	**Usuku**	**Isiginisha**

Appendix M: Case History

DURBAN UNIVERSITY OF TECHNOLOGY

INYUVESI YASETHEKWINI YEZOBUCHWEPHESHE

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:

Page 1 of 4

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

Appendix N: Physical Examination

DEPARTMENT OF CHIROPRACTIC

DUT DURBAN UNIVERSITY OF TECHNOLOGY

PHYSICAL EXAMINATION: SENIOR

Patient Name: ______________________ **File no:** __________ **Date:** __________

Student: **Signature:**

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

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

SYSTEM SPECIFIC EXAMINATION:

CARDIOVASCULAR EXAMINATION

RESPIRATORY EXAMINATION

ABDOMINAL EXAMINATION

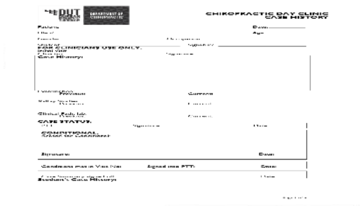
NEUROLOGICAL EXAMINATION

COMMENTS

Clinician: **Signature:**

Page 1

Appendix O: Cervical Spine Regional Examination



REGIONAL EXAMINATION – CERVICAL SPINE

Patient: ________________________ File No: ____________

Date: ____________ Student: ________________________

Clinician: ____________________ Sign: ____________________

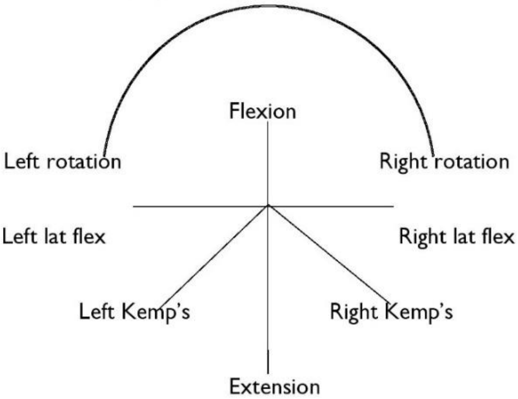
OBSERVATION:

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:

Dermatones	**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.			Wallenberg's test		

MOTION PALPATION & JOINT PLAY:

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

<u>BASIC EXAM: SHOULDER</u>:

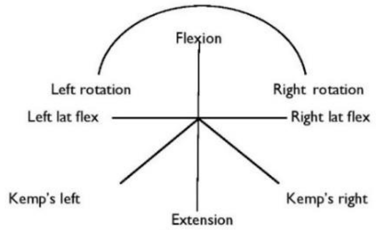
Case History:

ROM: Active:
Passive:
RIM:
Orthopaedic:
Neuro:
Vascular:

<u>BASIC EXAM: THORACIC SPINE:</u>

Case History:

ROM:



Motion Palpation:	
Orthopaedic:	
Neuro:	
Vascular:	
Observ/Palpation:	
Joint Play:	

Page 2 of 2

Appendix P: JPS Data Recording Table

JPS Data collection sheet

Goniometer readings: Participants code: Date: Initial Goniometer angle setting:	
Goniometer angle readings:	
Pre-intervention	Post-intervention

Appendix Q: Balance Data Recording Table

<u>Balance data collection sheet</u>

BBPBS readings: Participants code: Date:	
BBPBS index readings:	
Pre-intervention	Post-intervention

Appendix R: SOAPE Note

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INYUVESI YASETHEKWINI YEZOBUCHWEPHESHE

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

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

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

A:

0:

P:

E:

Special attention to: **Next appointment:**

EBCC References:

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

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

A:

O:

P:

E:

Special attention to: **Next appointment:**

EBCC References:

Appendix S: Plagiarism Report

The immediate effect of chiropractic cervical spinal manipulative therapy on joint position sense and balance in elderly participants in the eThekwini Municipality

ORIGINALITY REPORT

5%	3%	4%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

Appendix T: Proofreading Certificate

Helen Bond

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CERTIFICATE

Robyn Bonsma

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Dear Robyn

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Helen Bond (Bachelor of Arts, HDE)