The Effects of Cervical Spine Manipulation on Phonation in Patients with Muscle Tension Dysphonia

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Master of Arts in Speech-Pathology by research

by

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Declaration

I, Robin Mark Maris, hereby declare that the following dissertation was solely undertaken by myself and no help was provided from other sources than those allowed. All sections of the paper that use information developed by another author have been referenced. I am responsible for the content of the study and conclusions made. No part of this dissertation has previously been submitted for a degree at this or another University.

Signature: ________________ Date: _________________

Robin Mark Maris

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Abbreviations:

AHPCSA – Allied Health Professions Council of South Africa

BIS – Behavioural Inhibition System

CMT – Circumlaryngeal Manual Therapy

CSM – Cervical Spine Manipulation

DSI – Dysphonia Severity Index

ENT – Ear, Nose and Throat

F_0 – Average Fundamental Frequency

GRBAS – Grade of hoarseness, Roughness, Breathiness, Asthenia and Strain

HPCSA – Health Professions Council of South Africa

LMT – Laryngeal Manual Therapy

MCT – Manual Circumlaryngeal Therapy

MDVP – Multidimensional Voice Program

MRI – Magnetic Resonance Imaging

MTD – Muscle Tension Dysphonia

NHR – Noise to Harmonic Ratio

PET – Positron Emission Tomography

PMT – Postural Manual Therapy

RAP – Relative Average Pertubation

Shim – Shimmer Percent

SCM – Sternocleidomastoid

SLM – Specific Laryngeal Manipulation

SSEP – Somatosensory Evoked Potential

ST – Speech Therapist

VBAI – Vertebrobasilar Artery Insufficiency

VHI – Voice Handicap Index

VTD – Vocal Tract Discomfort

VTI – Voice Turbulence Index

Chapter 1: Introduction and Rationale

This study explores the effects of cervical spine manipulation on phonation in patients with Muscle Tension Dysphonia and ascertains whether these effects are temporary or permanent. In this section the key concepts involved in the research will be briefly defined and a rationale for the study will be developed.

Muscle Tension Dysphonia (MTD) is a condition characterised by excessive activity of the intrinsic and extrinsic laryngeal muscles which results in decreased phonatory function. MTD has many manifestations from hoarse, tense, weak voice to aphonia, all of which are extremely disabling for the patient. The aetiology of MTD is multifactorial stemming from both psychological as well as physiological anomalies and as a result of this, research into a multidisciplinary approach to treatment of this disorder has been produced and has yielded positive results. This type of research however, is rare in nature. In this study, the role of the chiropractor as part of the multidisciplinary voice care team, in laryngeal manipulation therapy will be explored. Because of the complexities involved in MTD, the consideration and treatment of all contributing factors by engaging an interdisciplinary approach is expected to yield the most favourable prognosis (Altman, Atkinson & Lazarus, 2005).

The reason for including the chiropractor in this multidisciplinary approach, is that patients suffering with MTD commonly present with certain musculoskeletal abnormalities, suprahyoid and infrahyoid muscle tightness, cervical spine tension and anterior head carriage being a few examples. These musculoskeletal issues contribute to a high riding larynx which alters the tension of the vocal cords resulting in disturbed speech (Rubin, Blake & Mathieson, 2007). Diaphragmatic function has also been shown to have a direct effect on lung volume which too affects the vertical position of the larynx during phonation (Iwarsson & Sundberg, 1998).

Manual therapy for voice disorders is a field that has only recently started to be explored and research into it is extremely limited. Studies on Laryngeal Manual Therapy (LMT) and Circumlaryngeal Manual Therapy (CMT) have shown a decrease in muscle tension of the suprahyoid and infrahyoid musculature, resulting in normalisation of the voice in patients suffering with MTD (Aronson, 1990; Roy et al., 1996; Roy et al., 1997; Roy et al., 2009; Mathieson et al., 2007; Lieberman et al., 2005).

Research into the field of cervical spine manipulation (CSM) has shown that the manipulation of motion segments of the vertebral column leads to decreased inhibition of the muscles innervated by their respective nerves (Tunnell, 2009, Brenner et al, 2007, Gill et al, 2007, Metcalfe et al, 2006, Cleland et al, 2004, Keller et al, 2000, Hertzog et al, 1999, Suter et al, 1999). This is thought to be achieved by restoring normal biomechanical integrity of the restricted vertebral motion segment thereby relieving any pressure on the associated nerve root (Murphy et al 1995, Lewit 1985, Korr 1979).

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As yet no studies into the effects of CSM on voice have been conducted but the neurophysiological effects of spinal manipulation, as mentioned above, provide insight into the possible mechanism of action of CSM on the extrinsic laryngeal muscles. This mechanism will be further explored in the literature review.

The research focussed on the effects of CSM on the suprahyoid, infrahyoid and diaphragm muscles. These muscles are innervated by nerve roots emanating from between the cervical vertebrae (Moore, 1992).

Decreased range of movement of the cervical spine will also result in altered length-tension relationships in the extrinsic laryngeal muscles which will negatively impact muscle function. CSM has been shown to have a positive effect on increasing joint range of movement (Paton, 2012) resulting in normalisation of muscle length and thereby improved functionality.

The key objective of this study was to ascertain whether CSM leads to a decrease in inhibition of the suprahyoid and infrahyoid musculature and the diaphragm, resulting in a lowering of the larynx and improved phonation.

We also aimed to see whether the combination of CSM and LMT was more effective than LMT alone and the effects of both treatment groups on vocal tract discomfort (VTD) which commonly accompanies the disorder. The results may indicate that CSM is effective in alleviating certain symptoms of MTD and may prove to be a useful adjunctive therapy in the multidisciplinary approach to the treatment of this condition.

Chapter 2: Literature Review

The literature review process involved article sourcing from Science Direct, Pubmed, Google, Google Scholar, JMPTonline and Elsevier. International and national articles were sourced through the University of Witwatersrand Library Intranet. The search was done in the English language and was based on a combination of key words including: Muscle Tension Dysphonia, Laryngeal Manipulative Therapy, Laryngeal Manual Therapy, Circumlaryngeal Manual Therapy, Voice Massage, Spinal Manipulation, Chiropractic adjustment, voice disorders, GRBAS scale, multi-dimensional voice program (MDVP) and laryngeal muscles. In order to access the most recent research material, articles were originally sourced from the period of 2010-2017. Due to elements of this research being the first of its kind, the search needed to be extended into the 1990's to access more literature to better establish a foundation for this study.

This chapter will outline the major concepts utilised in this research. MTD will be clearly defined along with the inclusion of its aetiology, presentation and the various musculoskeletal anomalies associated with the disorder. The extrinsic laryngeal muscles will be identified and their innervation and function explained in order to align them with the cervical spine manipulation segment of the literature review.

Laryngeal manipulative therapy which is used for reducing tension in these muscles will then be discussed along with its successes and limitations. Spinal manipulation and the neurophysiological and biomechanical effects thereof will be elucidated before linking this particular line of therapy to the hypothetical reduction of the musculoskeletal issues that present in patients suffering with MTD.

2.1 Muscle Tension Dysphonia

Muscle Tension Dysphonia (MTD) is a pathological condition of diverse aetiology. Patients suffering with MTD present with excessive tension of the extrinsic laryngeal musculature which alters the tension of the vocal cords resulting in decreased phonation (Van Houtte, Van Lierde & Claeys, 2009).

In the literature, many titles have become synonymous with MTD. Hyperfunctional dysphonia, mechanical voice disorder and laryngeal tension fatigue syndrome are a few examples of diagnoses used for patients suffering with MTD. The various synonyms have been used by therapists and physicians due to the varying etiologies and characteristics the condition presents with. Incorrect or strenuous vocalisation as well as psychological factors, certain personality traits, e.g. anxiety, and the presence of underlying pathology that may negatively impact phonation, influence the manifestation of MTD (Van Houtte et al., 2009).

MTD can be divided into two forms, primary or secondary. Dysphonia without concurrent vocal fold pathology and psychogenic or neurologic aetiology is classified as primary MTD. It occurs primarily in women and the dysphonia is related to abnormal biomechanical action of the larynx (Roy, 2003). Secondary MTD describes dysphonia with an underlying organic condition. It is not entirely clear whether MTD causes the organic pathology or vice versa as prolonged phonation in patients with MTD may alter the mucosa of the vocal cords (Verdolini, Rosen & Branski, 2005).

Furthermore, four patterns of MTD are most frequently encountered:

1. MTD 1 - Hypertonic posterior cricoaryteniod muscle causes laryngeal isometric contraction with posterior open chink.
2. MTD 2 – Midline adduction of the ventricular folds resulting in supraglottic contraction
3. MTD 3 - A decrease in space between the prominences of the arytenoids due to anterior-posterior contraction
4. MTD 4 – Extreme anterior-posterior contraction or squeeze

These patterns are observed during videostroboscopy of the larynx (Rubin, Sataloff and Korovin, 2006).

Patients with MTD predominantly present with pitch abnormalities, cervical neck tension and jaw tension (Altman et al., 2005). Other musculoskeletal abnormalities that are frequently encountered in MTD patients are weak deep cervical flexors and shortened sternocleidomastoid and stylohyoid muscles but most importantly, a high riding larynx (Rubin et al., 2007). Vocal tract discomfort (VTD) has also been found to be concomitant with MTD. This can be attributed to anatomically related muscles being used incorrectly during phonation resulting in increased muscular tension and pain (Mathieson, Hirani, Epstein, Baken, Wood & Rubin, 2007). Tight, tender and contracted paralaryngeal muscles are also palpable in MTD patients which results in decreased range of movement of the laryngeal apparatus and is experienced as stiffness (Rubin, Lieberman & Harris, 2000). For this reason the Vocal Tract Discomfort scale has been included as a measure in this study.

2.2 Anatomy of the extrinsic laryngeal muscles

The larynx is held in position by the external laryngeal musculature. Tension in the suprahyoid and infrahyoid muscles therefore alters the natural position of the larynx. This results in a disruption of normal position of the hyoid, thyroid, cricoid and arytenoid cartilages which alters the tension of the vocal cords leading to a change in phonation (Rubin et al., 2000).

2.2.1 Suprahyoid muscles

Table 1: Innervation and function of the suprahyoid muscles

MUSCLE	INNERVATION	FUNCTION
Geniohyoid	*C1 via the hypoglossal nerve	Pulls the hyoid bone anterosuperiorly, shortens the floor of the mouth and widens the pharynx
Stylohyoid	Facial nerve	Elongates the floor of the mouth by elevating and retraction the hyoid bone
Mylohyoid	Mylohyoid nerve (branch of the mandibular division of the trigeminal nerve)	Elevates the hyoid bone, the floor of the mouth and the tongue during swallowing and speaking
Anterior Digastric	Mylohyoid nerve	Raises and steadies the hyoid bone during swallowing and speaking
Posterior Digastric	Facial nerve	Raises and steadies the hyoid bone during swallowing and speaking

(Reproduced from Moore, 1992)

(*The geniohyoid muscle is different from the other supralaryngeal muscles in that it derives its innervation from C1 via the hypoglossal nerve while all other muscles in the group are supplied by the various cranial nerves (Moore, 1992). Therefore the geniohyoid muscle could be affected by CSM which will be discussed later)

2.2.2 Infrahyoid muscles

Table 2: Innervation and function of the infrahyoid muscles

MUSCLE	INNERVATION	FUNCTION
Sternohyoid	Ansa cervicalis	Depresses the hyoid bone after it has been elevated during swallowing
Sternothyroid	Ansa cervicalis	Depresses the hyoid bone and larynx
Thyrohyoid	Ansa cervicalis	Depresses the hyoid bone and elevates the larynx
Omohyoid	Ansa cervicalis	Depresses, retracts and steadies the hyoid bone

(Reproduced from Moore, 1992)

“The ansa cervicalis is a loop of nerves that are part of the cervical plexus which is comprised of the ventral rami of the first four cervical nerves. It lies superficial to the internal jugular vein in the carotid triangle” (Moore, 1992, p800). CSM could have a neurological and biomechanical effect on these muscles which will be explained in the spinal manipulation section of this review.

Research has shown that tension in the thyrohyoid muscle is readily palpable in MTD patients (Angsuwarangsee & Morrison, 2002) and another study has shown increased EMG readings in the supralaryngeal muscles, before and during phonation in these patients, further indicating excessive tightness of this particular group of muscles in MTD sufferers (Hocevar-Boltezar, Janko & Zargi, 1998). This provides further support for the investigation of cervical spinal manipulation to reduce tension in these muscles.

2.2.3 Diaphragm

Although the diaphragm is not classified as an external laryngeal muscle and its anatomical attachments are not relevant to this study, it has a direct effect on lung volume which has been shown to influence laryngeal position. Lower laryngeal position was seen in individuals with increased lung volume and it was also found that larynx position had a definite impact on pitch (Iwarsson & Sundberg, 1998). The diaphragm is innervated by the phrenic nerve which is comprised of branches of C3, C4 and C5 (Moore, 1992) and may therefore be impacted by the neurological effects of CSM which will be discussed later.

2.3 Laryngeal Manual Therapy (LMT)

Manual therapy has been used to combat muscle tightness in various conditions by therapists for many years although this type of therapy is only recently gaining popularity in the treatment of voice disorders.

Laryngeal Manual Therapy is an umbrella term used to describe the types of physical therapies that can be performed on the larynx and the extrinsic laryngeal musculature. The three most common treatments are classic laryngeal manual therapy, manual circumlaryngeal therapy (MCT) and voice massage (Mathieson 2011). The differences between classic LMT and MCT are that palpation is done prior to intervention in LMT as opposed to during intervention in MCT. MCT is usually performed with one hand while classic LMT uses both hands and MCT aims to increase the reduced thyrohyoid space while LMT does not address this (Aronson, 1990; Mathieson et al, 2007).

Voice massage is a Finnish massage technique which aims to improve ribcage mobility in breathing by targeting respiratory, articulatory and laryngeal muscles thereby relaxing other muscles used in phonation (Leppanen, Ilomaki, Laukkanen, 2010).

Laryngeal Manual Therapy has been documented in multiple studies as being an effective modality in reducing extrinsic laryngeal muscle tension thereby improving phonation in patients with voice disorders. The technique is a combination of soft tissue massage and muscular stretching applied to the extrinsic laryngeal muscles and in some cases laryngeal cartilage manipulation (Aronson, 1990; Roy et al., 1996; Roy et al., 1997; Roy et al., 2009; Mathieson et al., 2007; Lieberman et al., 2005). Acoustic analysis has shown evidence of vowel space expansion (Roy et al, 2009) and changes in formant transitions (Dromey et al, 2008) in MTD patients that have undergone LMT.

In a pilot study conducted by Van Lierde, De Ley, Clement, De Bodt and Cauwenberge (2004), patients that had undergone previously unsuccessful voice therapy were given twenty five sessions of LMT. Voice analysis was completed before and after the prescribed treatment using the GRBAS scale and the Dysphonia Severity Index (DSI). Positive changes were recorded in both for all patients in the study. DSI, aerodynamic measurement, acoustic analysis and voice range profile were also tested pre and post MCT in a group of healthy music students and again positive changes were seen. This could indicate that LMT may be effective in other areas of voice therapy and not solely with the treatment of MTD (D'haeseleer, Claeys, Van Lierde, 2013).

The types of therapy vary slightly amongst the different practitioners and although the studies to date are positive, there is a lack of randomised, controlled and blinded research. LMT has resulted in improved phonation in many of these studies but the mechanism of action is currently only hypothesised and more research needs to be conducted to determine the exact mechanism of action (Mathieson, 2011).

A study conducted by Kennard et al made use of what they termed specific laryngeal manipulation (SLM) to ascertain its effect on voice quality. The technique has similarities with LMT but also involves assessment of the jaw, the temporomandibular joint and the floor of the mouth. The study indicated that this type of LMT produced significant changes in voice quality (Kennard, Lieberman, Saaid, Rolfe, 2014).

There have also been comparative studies between LMT and other modalities in the treatment of dysphonia. A study comparing LMT and Transcutaneous Electrical Nerve Stimulation found that both treatments were able to elicit improvement in voice quality (Casisa Macedo Conde, Donalonso Siquera, Vendramini, Brasolotto, Jesus Guirro, Alves Silverio, 2017). Similar results were found when patients were treated with a combination of voice therapy and physical therapy (Craig, Tomlinson, Stevens, Kotogal, Fornadley, Jacobson, Garrett, Francis, 2015).

A systematic review and meta-analysis on LMT's for dysphonia showed that different types of LMT were equally effective in the treatment of dysphonic patients as direct voice therapy (Veis Ribeiro, Pedrosa, Alves Silverio, Behlau, 2017). The same study identified over two thousand studies and only three of these met the criteria for analysis and of the three all were flagged for moderate to high levels of bias, indicating again the need for more randomised, controlled and blinded research.

A study using physical therapy, stress management education and exercise for the treatment of MTD also showed improved Voice Handicap Index (VHI) scores as well as increased cervical and jaw range of motion. Improvements in cervical and jaw range of movement occurred in one hundred percent of participants (Tomlinson & Archer, 2015).

For the purposes of this study, I aimed to reproduce the LMT used by Mathieson et al which formed the baseline for my comparison participants. Acoustic analysis was used in this study and revealed that this particular form of LMT produced positive and measurable effects on patients with MTD (Mathieson et al, 2007). This was also true of other studies conducted (Dromey et al 2008, Roy et al 2009) and in a comparative study MCT was shown to be a superior form of treatment for MTD over vocalisation with abdominal breath support (Van Lierde, De Brodt, Dhaeseleer, Wuyts and Claeys, 2010).

2.4 Spinal Manipulation

Spinal manipulation, also called a chiropractic adjustment or a grade V mobilisation, is defined by the American Chiropractic Association as a high velocity, low amplitude, directional thrust delivered to a dysfunctional spinal segment with the aim of restoring or improving neuromusculoskeletal function.

Several theories exist regarding the neurology of spinal manipulation and there is sufficient research to create explanations of the effects but there is still a lack of proof to validate any individual theory (Halderman, 2000).

“A biomechanical aberration in the spine stimulates receptors in the spinal and paraspinal tissues. This in turn generates impulses which activate neural reflex centres in the spinal cord or higher centres, which causes somatovisceral responses in sympathetic and parasympathetic nerves or somato-somatic responses resulting in muscle spasm. This is known as the reflex theory of spinal manipulation" (Budgell, 2000, p105; Halderman, 2000, p113).

The pain relief theory relates to the change in cutaneous and muscular pain thresholds from the stimulation of osseous, muscular, ligamentous and neural elements of the spine as a result of manipulation. This is also known as central facilitation (Vernon, 2000).

The most readily accepted theory supporting the neurology of spinal manipulation is that of nerve compression. This theory suggests that spinal dysfunction causes nerve root compression which results in pain or other pathology (Halderman, 2000). Dysfunction of particular spinal segments may lead to altered neurological input into the particular motion segment which could result in a change in local muscle tone (Murphy et al 1995, Lewit 1985, Korr 1979).

Spinal manipulation causes a reduction in muscular inhibition (Tunnell, 2009, Brenner et al, 2007, Gill et al, 2007, Metcalfe et al, 2006, Cleland et al, 2004, Keller et al, 2000, Hertzog et al, 1999, Suter et al, 1999) which is achieved due to a transient decrease in motoneuron activity (Dishman and Bulbulian 2001, Dishman and Bulbulian, 2000). This decrease is thought to be due to the impact that spinal manipulation has on primary afferent neurons (Pickar JG, 2002) although the exact mechanism of action is currently unknown.

Further research indicates that when patients with radiculopathy were subjected to somatosensory evoked potential (SSEP) testing pre and post manipulation, they exhibited an increase in nerve conduction velocities in the post manipulation group. This was true for eighty five percent of the subjects (Collins & Pfleger, 1994). Cervical spine manipulation has also been shown to alter sensorimotor integration (Taylor & Murphy, 2007) giving further evidence of the neurological effects of such treatment.

Looking at the proposed neurological models outlined above, we can hypothesise that spinal dysfunction at the levels of C0-C5 could adversely affect the diaphragm, infrahyoid and suprahyoid musculature due to altered neurological input. This would then result in a change in laryngeal position created by abnormal muscle tone in the extrinsic laryngeal muscles. Altered muscle tone in the diaphragm would ultimately affect lung volume which has been shown to have a direct influence on laryngeal position (Iwarsson & Sundberg, 1998).

We can also surmise that eliminating cervical spine dysfunction through cervical spine manipulation should result in a normalisation of neurological input to the aforementioned muscles which would lead to decreased muscular inhibition resulting in improved laryngeal movement and therefore improved phonation.

A study using magnetic resonance imaging (MRI) assessed brain function of a patient with MTD pre and post LMT and it was found that there was over-activation of motor inhibition networks and of the amygdala, cingulate cortex, periaqueductal gray matter and hypothalamus in the pre-treatment group compared to the post-treatment group (Roy, Dietrich, Blomgren, Heller, Houtz, Lee, 2017). Research testing the effects of chiropractic treatment on cerebral metabolism using positron emission tomography (PET) revealed that glucose metabolism was reduced in the cerebellar vermis and visual association cortex and increased in the inferior prefrontal cortex, anterior cingulated cortex and middle temporal gyrus. These areas are known to influence pain reduction and sympathetic relaxation (Ogura, Tashiro, Masud, Watanuki; Shibuya, Yamaguchi, Itoh, Fukuda, Yanai, 2011). Although the neurological mechanism of action is not known, chiropractic manipulation and LMT have been shown to elicit changes in areas of the brain that affect the behavioural inhibition system (BIS) (Roy et al, 2017; Ogura et al 2011) which may help reduce anxiety that is commonly associated with MTD (Van Houtte et al., 2009) thereby reducing muscle tension resulting in optimal laryngeal movement and improved phonation.

From a purely biomechanical perspective, decreased range of movement of the cervical spine will result in altered length-tension relationships in the extrinsic laryngeal muscles causing them to become inhibited (Lieber and Bodine-Fowler, 1993). For example, decreased neck flexion as seen in MTD patients (Rubin et al, 2007) will create a shortening or contracting of the stylohyoid muscle decreasing its ability to function. This muscular inhibition can be further explained by analysing the microanatomy of skeletal muscle as follows:

Skeletal muscle consists of bundles of muscle fascicles, the fascicle is further divided into multiple groups of muscle fibres and muscle fibres themselves are comprised of thousands of myofibrils. Each myofibril is a grouping of thick and thin filaments and these groupings are organised into repeating functional units termed sarcomeres (Martini, Ober, Garrison, Welch and Hutchings, 1998). Figure 1 that follows illustrates the functional units of skeletal muscle.

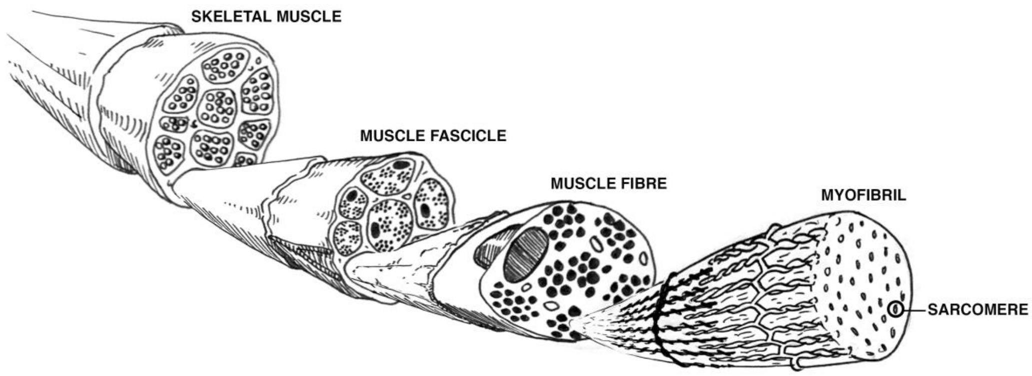


Figure 1: Functional units of skeletal muscle

Thin filaments are made up of actin chains which are twisted strands of G Actin protein. There is an active site on each G Actin molecule which has the ability to attach to a thick filament. These strands are called F Actin. The active sites are covered with another protein called tropomyosin which prevents bonding between actin and myosin. A third protein, troponin, binds to tropomyosin and G Actin and contains a receptor that binds to calcium (Martini et al, 1998). The thin filament is illustrated in figure 2 below.

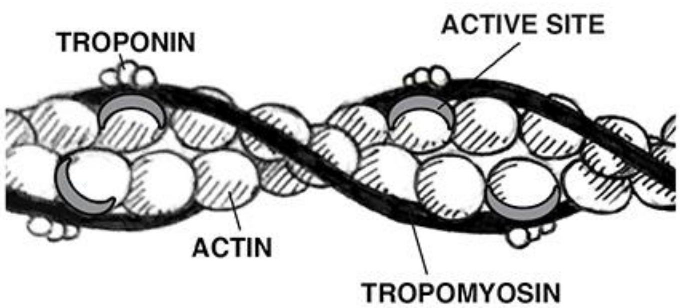


Figure 2: Thin filament

Thick filaments are groupings of myosin molecules, each of which have a head and a tail. The tail binds to tails of other myosin molecules and the heads, which are two globular protein subunits, bind to thin filaments during muscle contraction. When this action occurs they are also referred to as cross bridges (Martini et al, 1998).

The units of the sarcomere need to be expanded upon to properly understand the sliding filament theory of muscle contraction. In a resting sarcomere (Figure 3 below) these are:

1. A band – refers to the thick filaments in the centre of the sarcomere
2. M line – proteins that connect the centre of the thick filaments to each other
3. H zone – the area that exists on either side of the M line and only contains thick filaments
4. Zone of overlap – region where thin filaments are seen between thick filaments
5. I band – extends from A band to A band of adjacent sarcomeres and contains only thin filaments
6. Z lines – boundary between sarcomeres. Titin strands bind the Z line to the thick filaments

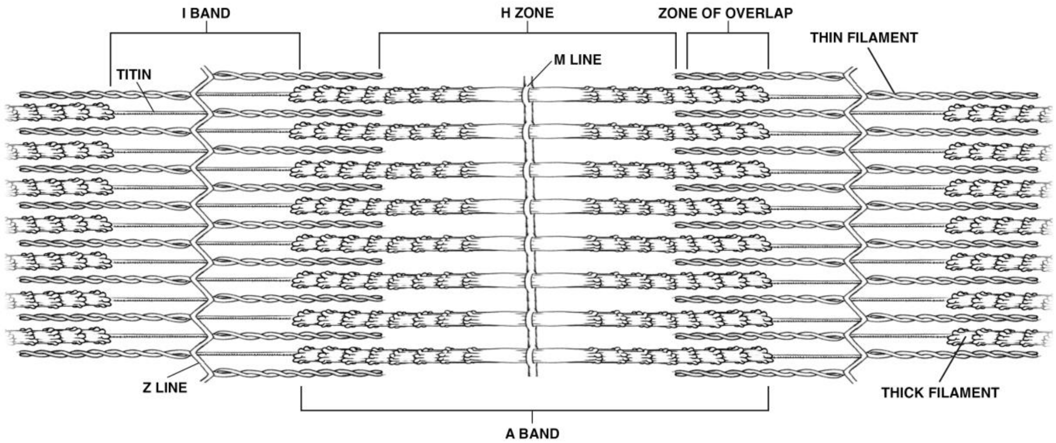
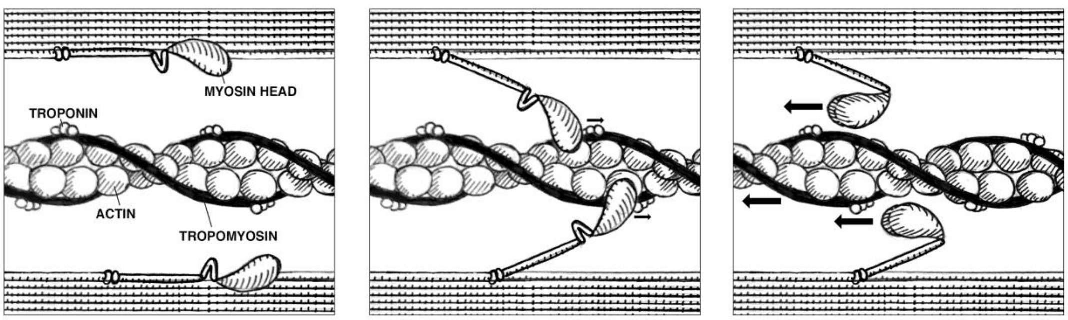


Figure 3: Sarcomere at rest

During contraction the width of the A bands remains unchanged but there is an increase in the zone of overlap and a decrease in size of both the H and I bands as well as a decrease in the distance between Z lines. This is made possible when the myosin head attaches to the active site on a G Actin molecule. The myosin head, which is initially pointing away from the M line, now pivots toward the M line pulling the thin filament towards it. This is termed the power stroke (Martini et al, 1998). These phases of muscle contraction are illustrated in Figure 4 below.



(a) Resting (b) Attachment (c) Power Stroke

Figure 4: Phases of muscle contraction

One can now see that an increase in length of a muscle will result in a decrease in the size of the zone of overlap leading to fewer cross bridge attachments. Conversely, a shortened muscle will cause a decrease in the size of the I band and H Zone. This results in a disruption of the normal orientation of the thick and thin filaments leading to decreased range of movement during the power stroke resulting in reduced or ineffective muscle contraction (Martini et al, 1998). The possible changes in muscle length/tension relationships explained previously are diagrammatically represented in figure 5 on the following page.

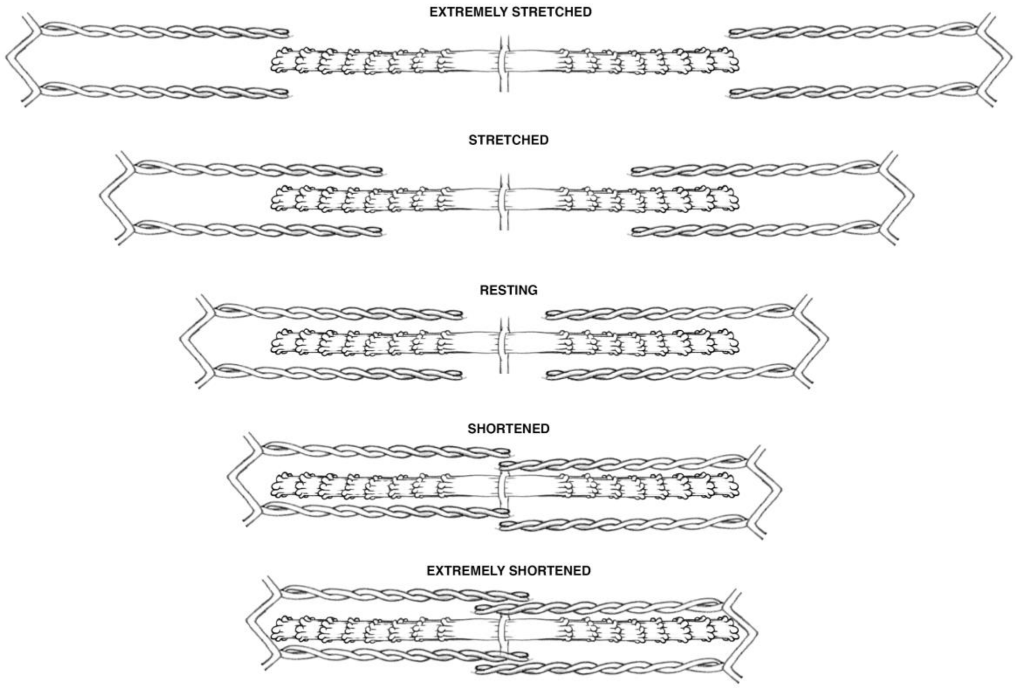


Figure 5: Length/tension relationships in a sarcomere

Spinal manipulation has been shown to increase cervical range of movement (Millan, Leboeuf-Yde, Budgell, Descarreaux and Amorim, 2012 and Paton, 2014) which could restore normal length-tension relationships in the associated muscles. Returning to the earlier example, cervical spine manipulation could restore neck flexion in patients with MTD and return the stylohyoid muscle to its normal resting length allowing for improved function.

Postural manual therapy (PMT) is a type of therapy that includes the treatment of the cervical and thoracic spine as well as the scaleneus, trapezius and sternocleidomastoid muscles and has been shown to improve voice quality (Kennard et al, 2014). Tomlinson and Archer (2015) found a correlation between increased cervical range of motion and improved VHI scores in MTD patients being treated with physical therapy. The increase in cervical range of movement could lead to correct anatomical alignment of the larynx and the supporting muscles, ligaments and tendons allowing for optimal vocal cord function (Kennard et al, 2014).

Problem Statement

The current research on manual therapy for patients with voice disorders has been shown to be successful in improving phonation but this research has typically been focused on either LMT or CMT. To date, no research exists on the effects of CSM on phonation. However, the neurological and biomechanical effects of CSM would indicate that an effect on phonation is plausible by influencing the muscles responsible for laryngeal movement. The proposed study therefore seeks to answer the following research question, ‘Does Cervical Spine Manipulation affect phonation in patients with Muscle Tension Dysphonia?’

Chapter 3: Methodology

This section contains details on the methodology of the proposed study. It outlines the research design, the participants, sampling, examination and treatment protocols and data collection and analysis.

3.1: Aims of the study

3.1.1 Primary aim

To ascertain whether CSM had an effect on phonation in patients suffering with MTD.

3.1.2 Specific objectives

- To measure the effects of LMT and CSM on phonation in patients with MTD
- To measure the effects of LMT only on phonation in patients with MTD
- To compare results of (1) versus (2). LMT alone has been shown to produce positive changes in phonation in MTD patients (Aronson, 1990; Roy et al., 1996; Roy et al., 1997; Roy et al., 2009; Mathieson et al., 2007; Lieberman et al., 2005). By adding CSM as an additional treatment with LMT and then comparing the results against LMT alone I should be able to ascertain whether CSM had an effect on phonation.
- To ascertain whether the effects of LMT and LMT combined with CSM were temporary or permanent

3.2: Research Design

The research takes the form of a descriptive true experimental design.

For research to be classified as a true experimental study it requires:

(1) Manipulation of the independent variable

(2) Holding all other variables in the research constant

(3) Participants in the experimental and control/comparison groups are equivalent with respect to the dependant variable before taking part in the experiment (Whitley 2002).

The independent variable in this study was CSM which was employed in the treatment/experimental participants and disregarded in the control/comparison participants. All other variables in the research situation including LMT, patient position pre and post-testing and patient position pre and post-treatment, remained constant. All participants in the study were MTD patients and were randomly assigned to either receive the experimental or comparison treatment.

The dependant variable was the decreased level of phonation which was equivalent across all participants in the research as it is the primary presenting characteristic of patients afflicted with MTD. The study therefore fulfilled the three defining criteria for a true experiment.

3.3: Site

The study was conducted with patients that were diagnosed with MTD by a speech pathologist and Ear, Nose and Throat surgeon in our private practice located in the Voice and Swallowing Centre in Parktown Johannesburg, South Africa. In our practice there is a specialised team of practitioners including speech therapists, a chiropractor, audiologists and an ear, nose and throat surgeon. This combination of practitioners in diverse fields allows us to tackle the multitude of symptoms commonly present in patients with voice disorders.

3.4: Sampling Procedure

This study made use of purposive sampling to recruit participants. In this form of sampling the researcher used his judgment to select the membership of the samples based on the goals of the research. It identified a sample of participants that were characteristic or representative of the study phenomena (Whitley 2002). Participants were purposively selected from the population in Gauteng that have presented with MTD at the Voice and Swallowing Centre.

3.5: Sample

3.5.1 Sample description

The sample for the research included individuals afflicted with MTD that presented to the Voice and Swallowing Centre. The study also made use of research assistants who were consenting allied health and health professionals, namely a speech therapist (ST) and an ear, nose and throat surgeon (ENT), and who assisted in the data collection process. Together with the researcher (Chiropractor) they formed part of a multidisciplinary team.

Inclusion criteria for MTD patients

- Men or women between the ages of 18 to 65 years
- Previously diagnosed with primary or secondary MTD
- Married or single
- Employed or unemployed
- Live in Gauteng

- Understand and have the ability to communicate in the English language

Exclusion criteria for MTD patients

- Previous traumatic cervical injury
- Previous cervical spine surgery
- Degenerative arthritis of the cervical spine
- Unstable Rheumatoid Arthritis of the cervical spine
- Vertebrobasilar Artery Insufficiency (VBAI)
- Previous history of stroke
- Persons with co-existing neurological impairments or conditions
- Acute Arthropathies
- Acute Fractures and dislocations
- Signs of ligamentous rupture or instability
- Bone malignancies and metastases
- Infections of bone and joint
- Acute Myelopathy
- Spondylolisthesis with progressive slippage
- Articular hypermobility
- Postsurgical joints
- Acute soft tissue injuries
- Demineralisation of bone
- Benign bone tumours
- Aneurysm
- Anticoagulant therapy

- Blood dyscrasias

These exclusion criteria are considered contraindications for spinal manipulation as they increase the possibility of an adverse event occurring during or post treatment.

Inclusion criteria for research assistants

- Should be a fully qualified ST or ENT
- Should be registered with the AHPCSA or HPCSA
- Should have at least one year working experience with patients with voice disorders

3.5.2 Sample size

There were 3 experimental participants and 3 comparison participants. The study aimed to have 15 experimental and 15 control participants but MTD is not extremely prevalent in the South African population and only 6 patients presented to our clinic with the disorder within the two year period that the research was conducted. This small sample size made the study statistically insignificant but allowed for trends to be identified for future research. Table 3 on the following page provides a description of each of the participants

Table 3: Description of participants

Patient No.	Rx	Age	Gender	Diagnosis	MTD Pattern	Complaint	Laryngostroboscopy Findings
1	LMT+ CSM	49	F	2^{o} MTD	1	Soft voice Vocal fatigue Difficulty swallowing	Right vocal cord paresis
2	LMT	57	F	2^{o} MTD	4	Hoarse voice Vocal strain	Left vocal cord paresis
3	LMT	46	F	2^{o} MTD	1	Soft voice Difficulty swallowing	Thickened vocal cords Dilated vessels Possible superior laryngeal and recurrent laryngeal nerve paresis
4	LMT+ CSM	42	F	2^{o} MTD	1	Prolonged voice loss	Weak vocal cord closure Bowing of vocal cords Neurological weakness
5	LMT	20	M	2^{o} MTD	1	High pitched voice Soft voice Pain when vocalizing	Bilateral vocal cord fissures
6	LMT+ CSM	40	F	2^{o} MTD	1	Soft voice Difficulty swallowing	Bilateral vocal cord paresis

All of the patients that took part in the study were diagnosed with secondary MTD. The majority of participants presented with type 1 secondary MTD which is when a hypertonic posterior cricoaryteniod muscle causes laryngeal isometric contraction with posterior open chink. One patient presented with type 4 secondary MTD which is characterised by extreme anterior-posterior contraction or squeeze.

3.6: Data collection tools

Data was collected through a self-rating VTD scale, recording analysis using MDVP and perceptual evaluation by speech therapists using the GRBAS scale.

3.6.1 Vocal Tract Discomfort (VTD) scale

The VTD scale was introduced by Mathieson et al as VTD is associated with MTD (Mathieson et al 2007). The scale details the nature of the discomfort experienced by the participant as well as the frequency and severity of the symptoms. It was completed by both the experimental and control participants before the initial voice recording and was taken prior to patient examination by the chiropractor. A second VTD scale was completed post LMT along with a second voice recording from the control participants and post LMT, CMT with a second voice recording from the experimental participants. A third VTD scale was done one week post treatment. These values were compared and descriptively analysed in order to determine which form of treatment led to a greater reduction in VTD and whether the results of these treatments were permanent or temporary.

3.6.2 Multidimensional Voice Program (MDVP)

MDVP has been shown to be effective in the analysis of voice disorders (Christmann, Brancalioni, Ramos de Freitas, Vargas, Keske-Soares, Mezzomo, Mota 2015; Zelcer, Henri, Tewfik, Mazer 2002; Kent, Vorperian, Duffy 1999). The program was relatively simple to use, analysis was automatic and completed in a very short space of time. The version of MDVP used in this study could evaluate five parameters of vocal function and then displayed them graphically for visualisation.

Table 4: Multi-Dimensional Voice Program Acoustic Parameters

Parameter	Symbol
Average Fundamental Frequency	Fo
Relative Average Perturbation	RAP
Shimmer Percent	Shim
Noise to Harmonic Ratio	NHR
Voice Turbulence Index	VTI

- Average Fundamental Frequency: The lowest frequency in a periodic waveform (Titze, 1994).
- Relative Average Perturbation: Short term variability in fundamental frequency, also called Jitter (Titze, 1994).
- Shimmer Percent: Short term variability in amplitude (Titze, 1994).
- Noise to Harmonic Ratio: Measure of the proportion of harmonic sound to noise (amplitude and frequency variations, turbulence noise, sub-harmonic components and/or voice breaks) and measured in decibels (Ferrand, 2002).
- Voice Turbulence Index: "Voice Turbulence Index is an average ratio of the spectral inharmonic high frequency energy in the range 2800-5800 Hz to the spectral harmonic energy in the range 70-4500 Hz in areas of the signal where the influence of the frequency and amplitude variations, voice breaks and sub-harmonic components are minimal. VTI measures the relative energy level of high frequency noise. It correlates primarily with the turbulence caused by incomplete or loose adduction of the vocal folds." (Di Nicola, Fiorella, Spinelli, Fiorella, 2006, p 62).

This makes the program extremely versatile as it allowed for the diagnosis of a multitude of acoustic disorders.

3.6.3 GRBAS scale

The GRBAS scale is an ordinal scale (Appendix D) used by therapists in perceptual evaluation of voice disorders. GRBAS stands for Grade of hoarseness, Roughness, Breathiness, Asthenia and Strain. These were the characteristics of the dysphonia being assessed and were classified as either mild, moderate or severe. 0 = Normal; 1 = Mild; 2 = Moderate; 3 = Severe. Results are shown in the form $G_2R_1B_1A_0S_1$ (Hirano 1981). It is the most utilised and researched scale in voice assessment and has been shown to be reliable and valid ((Nemr , Simoes-Zenari , Cordeiro, Tsuji, Ogawa, Ubrig, Menezes 2012; Carding, Wilson, MacKenzie, Deary 2009; De Bodt, Wuyts, Van De Heyning, Croux 1997).

3.6.4 Laryngostroboscopy

Laryngostroboscopy refers to the examination of the internal structures of the larynx with the use of a laryngeal endoscope to view vocal cord vibrations. It is extremely effective in identifying vocal cord pathology (Omori 2011) and has been shown to be reliable when assessing the static structures of the larynx (Yiu, Lau, Ma, Chan, Barrett 2013).

3.7: Research procedure

- Ethical clearance from the university of the Witwatersrand Human Research Ethics Committee
- Information to participants and research assistants
- Consent from participants and research assistants
- Data collection
- VTD scale, GRBAS scale and multidimensional voice program collation and description

- Data analysis

Each step of the research process is described below.

3.7.1 Ethical Clearance

Clearance from the University of the Witwatersrand Human Research and Ethics Committee (Medical) was granted prior to commencement of the study. The clearance certificate number is M160812 (Appendix 1).

In order to ensure that the research was carried out in an ethical manner, the researcher had to ensure that all resources were respectfully managed, contributions and guidance from others was acknowledged, the research was completed methodically and competently, the results were accurate and the consequences for society were considered (Brink et al 2012). The research was never conducted at the expense of the participants and said participants were informed of the benefits, risks, autonomy and confidentiality of the study (Brink et al 2012). This was made available in the information sheet.

Side effects of cervical spine manipulation can be divided into two groups, minor adverse events and major adverse events. Minor adverse events following cervical spine manipulation are relatively common, non-serious and transient whereas the risk of a serious adverse event, immediately or up to seven days post treatment is recorded as low to very low (Thiel, Bolton, Docherty, Portlock 2007; Ernst 2007; Assendelft, Bouter, Knipschild 1996).

Minor adverse events are classified as a worsening of presenting symptoms or onset of new symptoms. Headache, stiffness, local and/or radiating discomfort and fatigue are symptoms that have presented within four hours of spinal manipulation and resolved in the preceding twenty four hours (Cagnie, Vink, Beemaert, Cambier 2004; Senstad, Leboeuf-Yde, Borchgrevink 1996).

Fainting/dizziness/light headedness has been reported immediately post manipulation in 0.1% of cases and 4% of cases 7 days post manipulation. The total occurrence of these events is approximately 1.3% of all cases of cervical spine manipulation (Thiel, Bolton, Docherty, Portlock 2007). Myalgia and radiculopathy have been reported to occur in 1.5% of cases of cervical manipulation (Thiel, Bolton, Docherty, Portlock 2007).

Major Adverse Events are classified as events where the patient is referred to hospital, has severe onset or worsening of symptoms immediately after treatment and/or has resulted in persistent or significant disability or incapacity. These major adverse events are extremely uncommon and can mostly be avoided by adhering to prudent practice guidelines (Rivett 1995).

Fractures, joint dislocations, prolapsed discs, ligament sprains or tears, muscular strains or tears, Brown-Sequard syndrome, chronic radiculopathy, chronic myelopathy, vertebral artery occlusion and stroke are major adverse events that have been rarely associated with cervical spine manipulation. These adverse events have been reported in the literature to occur immediately post manipulation in approximately 0.01% of cases of manipulation and 7 days post manipulation in 0.02% of cases. Resulting in an approximate total risk of a major adverse event being 0.06% (Thiel, Bolton, Docherty, Portlock 2007).

The complication rate from cervical spine manipulation is estimated to be between 5 and 10 per 10 million manipulations (Hurwitz, Aker, Adams, Meeker, Shekelle 1996). Other studies have reported similar estimations (Stevinson and Ernst 2002; Henderson and Cassidy 1988). Prospective studies have shown the incident rate for complications resulting from spinal manipulation was 0.21% per manipulation and 0.42% per patient (Rivett and Milburn 2013). A retrospective study in Canada was conducted over a 10 year period extending from 1988 to 1997 to assess the risk of vertebral artery dissection after cervical manipulation. Based on this study an estimated 134 466 765 cervical manipulations were performed over the period and 23 cases of vertebral artery dissection were reported. This gave a calculation of 1 vertebral artery dissection per 5 846 381 cervical manipulations (Haldeman, Carey, Townsend, Papadopoulos 2002).

A South Africa specific study to determine the prevalence of complications of manipulative therapy recorded only 52 complications in 228 050 manipulations. 1 cerebrovascular accident was reported and all other complications were classified as minor (Michaeli 1993).

Most adverse events that were reported following cervical spine manipulation involved manipulation with a rotational movement of the cervical spine (Ernst 2002; Assendelft, Bouter, Knipschild 1996; Terret and Kleynhans 1992; Martienssen and Nilsson 1989). The adjustment that was utilised in this study was a modified version of the Cervical Break technique which only employed a lateral flexion movement when manipulating. No rotational type manipulation was used in the interest of patient safety.

Only the researcher and supervisor had access to the data obtained from the research and confidentiality was maintained as no participant information appeared on any of the forms used. Should a participant have wished to view the results of the study, a summary would have been made available. Data was stored in the Department of Speech and Language Pathology at the University of the Witwatersrand and will be destroyed after five years should there be no publications.

3.7.2 Information to participants and research assistants

An information sheet was provided to both participants and research assistants in order to clearly and comprehensively inform them about their participation in the study and invite them to join. This information sheet contained the researcher's contact details, the data gathering procedure and statement that the participants were free to withdraw at any time. Privacy assurance regarding personal information was explained and a consent form was signed once participation was acknowledged. (Appendix 2 and 3)

3.7.3 Consent form

Participants were made aware that participation in the study was completely voluntary and they could accept or decline to participate. The consent form included:

- The research title
- Outline of research activities

- Title and position held by the researcher
- Short and long term purpose of the study
- Proposed sample and reason why they were chosen
- Data collection methods and procedures
- Risks associated with manual therapy
- Confirmation of anonymity and confidentiality
- Voluntary nature of participation
- Availability of the researcher to answer any questions
- Contact details of the researcher

3.7.4 Data collection

The participants were selected after laryngostroboscopic evaluation by an ENT surgeon and a speech therapist and a diagnosis of MTD was confirmed. Initial readings were obtained through completion of the VTD scale and recordings using MDVP analysis.
The participants were then examined by the chiropractor.

Palpatory examination was done initially to determine the resistance and tension of the extrinsic laryngeal musculature, it was done extremely gently in order to not make the patient apprehensive as this would have created unnecessary cervical muscle tension which may have obscured the clinicians observations. Higher levels of muscular resistance have been associated with higher levels of discomfort during palpation (Mathieson et al 2009).

The patient was seated correctly in a low back chair ensuring a straight and supported spine and the head in the neutral position. The patient was asked to relax the shoulders, mandible and tongue and palpation commenced with the clinician standing behind the patient, using the pads of the index, second and third fingers (Mathieson et al 2009).

The examination began with assessment of the entire length of the sternocleidomastoid muscle (SCM) bilaterally, starting at the mastoid attachment and ending at the sternal attachment. The dominant hand was used to palpate the supralaryngeal region and the opposite hand cradled the occiput to stabilise the head and prevent movement during palpation. The examiner then palpated upwards and backwards from the middle of the mandible towards the hyoid bone and then progressed to the remainder of the supralaryngeal muscles (Mathieson et al 2009).

The thyroid was then palpated. Gentle lateral force was applied alternately to the thyroid lamina using the pads of the examining fingers. Resistance to this lateral digital pressure indicated tense extrinsic laryngeal musculature (Mathieson et al 2009).

The clinician then placed the digits of one hand horizontally across the neck of the patient with the lowest fingers at the level of the clavicle. Three fingers between the level of the clavicle and the lower level of the cricoid cartilage indicated a high-held larynx, two fingers, a neutral positioned larynx and one finger, a lowered larynx. These dimensions may vary slightly due to size discrepancies of both the patient’s neck and the examiners hands (Mathieson et al 2009).

The hyoid bone was then palpated and tenderness over the area was associated with tension in the paralaryngeal musculature. The examination took approximately four minutes (Mathieson et al 2009). Table 5 below details the cervical spine examination findings for each participant.

Table 5: Cervical spine regional examination findings

Patient No.	Cervical Spine Assessment Findings
1	• Anterior head carriage • High-held larynx • Right shoulder slightly elevated • Decreased active left and right rotation, extension and right lateral flexion range of movement • Positive Kemp's test C3/4 on the right • C2 left lateral flexion restriction • C3 right rotation and lateral flexion restrictions • C4 right rotation and lateral flexion restrictions
2	• Anterior head carriage • High-held larynx • Bilateral active sternocleidomastoid myofascial trigger points • Decreased active left and right rotation range of movement • C3 left anterior rotation restriction • C4 right anterior rotation restriction
3	• Scars from previous radiation and surgery for lymphoma • High-held larynx • Decreased active flexion and extension range of movement • Decreased and painful active right rotation and lateral flexion and left rotation and lateral flexion range of movement • Active bilateral sternocleidomastoid myofascial trigger points • C2 left rotation and lateral flexion restrictions • C3 right rotation and lateral flexion restrictions
4	• Anterior head carriage • Visibly elevated larynx • Bilateral sternocleidomastoid muscle tightness • Extreme cricothyroid muscle tenderness • Decreased active left and right rotation, left lateral flexion and flexion range of movement • Decreased and painful active right lateral flexion range of movement • Active bilateral sternocleidomastoid and cricothyroid myofascial trigger points • C2 and C3 left anterior rotation restrictions • C2 and C3 right anterior rotation restrictions • C3 right lateral flexion restriction
5	• Anterior head carriage • High-held larynx • Bilateral sternocleidomastoid muscle tightness • Decreased active right rotation range of movement • Hypertonic anterior strap muscles • Active right sternocleidomastoid myofascial trigger points • C2 and C3 left anterior rotation restrictions • C2 and C3 right anterior rotation restrictions • C3 right lateral flexion restriction
6	• Bilateral sternocleidomastoid muscle tightness • High-held larynx • Active right sternocleidomastoid myofascial trigger points • Decreased and painful right rotation and lateral flexion active range of movement • C2 left anterior and posterior rotation restrictions • C2 and C3 right anterior rotation and lateral flexion restrictions

The chiropractor then began with Laryngeal Manual Therapy.

LMT treatment

The position for LMT was very similar to that for the palpatory examination and was a combination of kneading, stretching and rotational massage of the paralaryngeal muscles. The treatment began with bilateral massage of the SCM's and began at the least tense point on the muscle and progressed to the point of greatest tension. These points were generally located at the origin, insertion and belly of the muscle. Equal pressure applied on the SCM's simultaneously may exert pressure on the carotid sinus and should be avoided (Mathieson et al 2009).

Once the SCM's were relaxed, the clinician progressed to treatment of the supralaryngeal region. The dominant hand kneaded the area while the opposite hand supported the occiput to prevent backward movement when pressure was applied during treatment. Massage was applied backwards and upwards from the midline of the mandible with the pads of the index, second and third fingers. The clinician then performed the same procedure from the body of the mandible toward the larynx. These two stages were repeated until maximum relaxation of the muscles was achieved while trying to avoid patient discomfort (Mathieson et al 2009).

In the case of a high riding larynx, the clinician could now contact the superior edge of the thyroid cartilage bilaterally and firmly depress the larynx. Following this, the clinician then contacted both thyroid lamina and applied lateral pressure. If lateral movement of the larynx increased it indicated a reduction of paralaryngeal muscle tension. The patient was then asked to swallow and speak (Mathieson et al 2009).

Improvements in voice quality post LMT treatment is often immediate and marked (Mathieson et al 2009, Roy et al 1998, Roy et al 1997, Roy and Leeper 1993). Changes in formant transitions (Dromey et al 2008) and improvements in articulatory acoustics (Roy et al 2009) have been documented after successful LMT. The above improvements were documented after one session of LMT in previous research as they were assessing immediate change in phonation Consequently this study limited the treatment sessions to one in order to attempt to reproduce similar results obtained from the preceding studies when performing LMT. The same reasoning applies for the single session of CSM provided for the experimental participants. Completion of a second VTD scale and a second recording using the MDVP was performed at this stage in the control group only.

<u>CSM treatment</u>

The experimental participants were treated with cervical spine manipulation at this stage. After successful LMT the patient remained seated and the patient was set up for cervical manipulation of the dysfunctional motion segments. The technique was a modified seated version of the cervical break described in States Manual. The patient remained seated during the manipulation procedure as opposed to lying supine in order to prevent any alteration in cervical muscle tension and position. The change of position could have created a lack of consistency of the independent variables associated with the study (Whitley 2002). This particular technique was chosen for its versatility as it is indicated for use in the treatment of cervical dysfunction at all levels, i.e. C0 to C7, and in multiple directions (States 1991). The vertebral levels manipulated for each participant correlate with the respective motion restrictions indicated in table 5.

The position of the chiropractor was standing posterior or posterolateral to the seated patient on the homolateral side of the listing. The contact hand was the chiropractor's anterior hand and skin slack was removed in a posterior to anterior direction with the exception of a hyperlordotic cervical spine where it would be removed anterior to posterior. The indifferent hand cupped the ear with the palm and the index finger and third digit split the sternocleidomastoid muscle (States 1991).

The line of drive of thrust was straight across in line with the eyes for all listings. A slight cephalad line of drive was included for cervical segments that were identified as being positioned inferiorly (States 1991). No rotational adjustments of the cervical spine were employed in this study in order not to have placed any undue pressure on the vertebral artery.

Post manipulation, the experimental participants were asked to complete the VTD scale and do their second recording using MDVP.

Both experimental and control participants were required to return in one week where a further recording was made using MDVP and a third VTD scale completed in order to assess whether any changes were temporary or permanent. Two patients did not return for the one week follow up.

All recordings were then randomly perceptually evaluated by a qualified speech therapist using the GRBAS scale. The speech therapist was blinded as to whether the readings were pre-treatment, post-treatment or those taken one week after treatment.

3.8: Data Analysis

Three sources of data were extrapolated descriptively. The VTD scale was analysed in order to establish the nature of the discomfort, the frequency of the sensation/symptom and the severity of the sensation/symptom. The GRBAS scale was scrutinised in order to obtain a perceptual evaluation of vocal quality pre-treatment, post-treatment and one week post-treatment. Multi-dimensional voice program analysis was studied in order to establish which elements of voice were affected in both experimental and control participants. The information extracted described the sample by identifying participants that exhibited changes in VTD and phonation and also highlighted changes in specific aspects of phonation if they were noted. The findings from the two groups were compared and correlated in order to uncover which form of treatment yielded a more positive result.

3.9: Reliability and validity

The VTD scale is a psychometric test that when subjected to discriminative validity, is able to discriminate between MTD patients and healthy individuals. Cronbach α .77 and 0.73 for VTD frequency and severity subscales confirmed internal consistency. "Correlations between VTD frequency and severity subscales and VHI total scores proved construct validity and test-retest reliability showed an interclass correlation coefficient of 0.91 for the severity subscale and 0.93 for the frequency subscale which is excellent" (Torabi, Khoddami, Ansari and Dabirmoghaddam 2015, p711). Smallest detectable change values and standard error of measurement for severity and frequency are acceptable. No systemic bias was identified through the Bland-Altman analysis which combined with the information presented above, leads me to conclude that the VTD scale is reliable and valid when measuring vocal tract sensations in patients (Torabi, Khoddami, Ansari and Dabirmoghaddam 2015).

Kent et al found that MDVP was effective and reliable in analysing neurogenic voice dysfunction and the GRBAS scale has also been shown to be reliable and valid (Nemr et al 2012; Carding et al 2009; De Bodt, Wuyts et al 1997). Laryngostroboscopic evaluation has also been shown to be reliable in the evaluation of the static structures of the larynx (Yiu et al 2013).

3.10: Implications

The research aimed to provide insight into the multidisciplinary approach to the treatment of MTD. It proposed to highlight how patients with the disorder may benefit from the addition of cervical spine manipulation into their treatment regime. It may also result in further research into spinal manipulation and its effects on muscles but in various fields, not only in the realm of voice pathology.

Chapter 4: Results

In this chapter the results for the MDVP, VTD scale and the GRBAS scale have been tabulated and discussed for each participant. The experimental (LMT+CSM) participants are listed first followed by the control (LMT) participants and then a final summary comparing the results (MDVP, VTD and GRBAS) between the two groups.

4.1: Experimental participant results (LMT and CSM)

There were three experimental participants represented numerically as patients 1, 4 and 6. Numbers were assigned when participants were randomly selected for either the experimental or the control treatment and simply indicate the position that they participated in in the study i.e. 1 = first participant; 6 = last participant.

4.1.1 Patient 1

Table 6: MDVP results for patient 1

Patient	Parameter	Pre	Post	1wk Post	Norm	Unit	STD(f)	Thresh
1	F_0	171.116	207.022	223.347	243.973	Hz	27.457	
	RAP	4.768	5.938	4.765	0.378	%	0.214	0.68
	Shim	23.043	18.756	10.14	1.997	%	0.791	3.81
	NHR	0.652	0.558	0.254	0.112		0.009	0.19
	VTI	0.219	0.225	0.143	0.046		0.012	0.061

Results from the MDVP showed an increase in F_0, RAP and VTI values and a decrease in Shim and NHR values immediately post intervention. The increase in F_0 brought the values closer to the norm while RAP and VTI values moved away. The decrease in Shim and NHR brought the values closer to the norm. All parameters were closer to normal values when readings were taken one week post treatment. This indicates that the intervention was successful in altering voice parameters and the changes were long lasting.

Table 7: VTD scale for patient 1

Sensation	Frequency	(0-6)	Severity	(0-6)
	Pre	1 wk Post	Pre	1 wk Post
Burning	4	4	3	3
Tight	6	5	5	5
Dry	4	3	3	3
Aching	2	5	2	5
Tickling	2	2	2	2
Sore	1	5	3	5
Irritable	2	3	2	3
Lump in throat	6	6	6	6

The VTD Scale showed a decrease in frequency of tightness and dryness one week post treatment and an increase in both frequency and severity of aching, soreness and irritability. Although these changes were not drastic they could possibly be due to the nature of the manual therapy and be reported as post treatment discomfort.

Table 8: GRBAS scale for patient 1

	Pre	Post	1 wk Post
G (Grade of hoarseness)	3	3	3
R (Roughness)	3	1	1
B (Breathiness)	3	3	3
A (Asthenia)	3	3	3
S (Strain)	0	2	1

GRBAS readings indicated a decrease in roughness immediately post treatment and one week post treatment and an increase in strain immediately post treatment followed by a decrease one week post treatment. The increase in strain immediately post treatment may be attributed to post treatment discomfort.

When comparing MDVP, VTD and GRBAS results for participant 1, it was seen that the data is inconsistent. MDVP, being the more objective measure, showed some improvements and some worsening of readings immediately post treatment and then an improvement across all parameters one week post treatment indicating an overall improvement in phonation. This was accompanied by a decrease in frequency of tightness and dryness (seen as positive) and an increase in frequency and severity of aching, soreness and irritability (seen as negative) on the VTD scale. One parameter on the GRBAS scale, roughness, showed improvement while another, strain, worsened. Even though the VTD and GRBAS scales are subjective, there is no visible correlation between their individual results and when compared with each other and with MDVP.

4.1.2 Patient 4

Table 9: MDVP results for patient 4

Patient	Parameter	Pre	Post	1wk Post	Norm	Unit	STD(f)	Thresh
4	F_0	127.269	94.774	N/A	243.973	Hz	27.457	
	RAP	3.282	2.029	N/A	0.378	%	0.214	0.68
	Shim	13.42	10.041	N/A	1.997	%	0.791	3.81
	NHR	0.234	0.177	N/A	0.112		0.009	0.19
	VTI	0.043	0.025	N/A	0.046		0.012	0.061

MDVP showed a decrease in all parameters immediately post treatment in this patient. Unfortunately no values for the one week post treatment period were obtained as the patient did not return to have these measurements taken.

Table 10: VTD scale for patient 4

Sensation	Frequency	(0-6)	Severity	(0-6)
	Pre	1 wk Post	Pre	1 wk Post
Burning	2	N/A	2	N/A
Tight	6	N/A	6	N/A
Dry	5	N/A	5	N/A
Aching	5	N/A	5	N/A
Tickling	2	N/A	4	N/A
Sore	5	N/A	5	N/A
Irritable	6	N/A	6	N/A
Lump in throat	6	N/A	6	N/A

VTD scale could not be compared because of failure of the patient to return for one week post treatment measurements.

Table 11: GRBAS scale for patient 4

	Pre	Post	1 wk Post
G (Grade of hoarseness)	1	3	N/A
R (Roughness)	3	3	N/A
B (Breathiness)	1	0	N/A
A (Asthenia)	1	1	N/A
S (Strain)	3	2	N/A

GRBAS scale showed an increase in hoarseness and strain but a decrease in breathiness immediately post treatment. Data was unavailable for the one week post treatment period due to the patient failing to arrive for measurements.

The MDVP results for patient 4 showed that all parameters decreased. F_0 and VTI values moved further from accepted norms which is seen as negative but the decline in RAP, Shim and NHR resulted in their values moving closer to normal values which is seen as positive. GRBAS results showed an improvement in breathiness but a worsening of hoarseness and strain, again indicating that the results are inconsistent and inconclusive.

4.1.3 Patient 6

Table 12: MDVP results for patient 6

Patient	Parameter	Pre	Post	1wk Post	Norm	Unit	STD(f)	Thresh
6	F_0	196.067	185.992	271.158	243.973	Hz	27.457	
	RAP	0.241	1.185	1.057	0.378	%	0.214	0.68
	Shim	3.541	9.995	5.048	1.997	%	0.791	3.81
	NHR	0.142	0.174	0.14	0.112		0.009	0.19
	VTI	0.042	0.027	0.074	0.046		0.012	0.061

MDVP readings for this patient indicated a decrease in F_0, RAP and VTI and a large increase in Shim and an increase in NHR immediately post treatment. A significant increase in F_0 as well as an increase in VTI was seen one week post treatment and a decrease in RAP, Shim and NHR readings.

Table 13: VTD scale for patient 6

Sensation	Frequency	(0-6)	Severity	(0-6)
	Pre	1 wk Post	Pre	1 wk Post
Burning	2	2	1	3
Tight	2	2	5	3
Dry	4	2	5	3
Aching	2	2	2	3
Tickling	2	0	1	0
Sore	2	2	2	3
Irritable	4	0	5	0
Lump in throat	1	2	1	3

A decrease in frequency of dryness, tickling and irritability and an increase in the frequency of a lump in the throat sensation was reported. The severity of burning, aching, soreness and lump in throat increased but the severity of tightness, dryness, tickling and irritability decreased in this patient.

Table 14: GRBAS scale for patient 6

	Pre	Post	1 wk Post
G (Grade of hoarseness)	1	2	1
R (Roughness)	1	2	1
B (Breathiness)	0	0	0
A (Asthenia)	0	1	0
S (Strain)	0	2	0

All GRBAS readings with the exception of breathiness increased immediately post treatment. Pre-treatment and one week post-treatment values were identical.

The change in MDVP values for patient 6 immediately post treatment, regardless of whether they increased or decreased, moved further away from normal values which could be viewed as negative and this remained the case one week post treatment which the exception of F_0 and NHR which moved closer to normal values and seen as positive. There was also inconsistent data in the VTD scale for this patient as multiple parameters improved while others regressed. The same can be said for the GRBAS scale results which showed a decline in voice quality immediately post treatment (this could be attributed to increased anxiety post treatment or post treatment discomfort) followed by a return to original values one week post treatment. The variation in the parameters across all three scales makes the results for this patient inconclusive as well.

4.2: Control participants results (LMT only)

The control/comparison patients were represented numerically as patients 2, 3 and 5.

4.2.1 Patient 2

Table 15: MDVP results for patient 2

Patient	Parameter	Pre	Post	1wk Post	Norm	Unit	STD(f)	Thresh
2	F_0	160.751	169.298	N/A	243.973	Hz	27.457	
	RAP	0.752	1.162	N/A	0.378	%	0.214	0.68
	Shim	2.395	4.178	N/A	1.997	%	0.791	3.81
	NHR	0.113	0.135	N/A	0.112		0.009	0.19
	VTI	0.016	0.049	N/A	0.046		0.012	0.061

Results from the MDVP showed an increase in F_0, RAP, Shim, NHR and VTI. F_0 and VTI climbed closer to normal values while RAP, Shim and NHR were significantly higher than their respective norms. Unfortunately the data for the one week post treatment reading was corrupted and it was not possible to ascertain whether or not the changes were permanent or if there was further improvement or regression. The VTD scale below however indicated an overall improvement.

Table 16: VTD scale for patient 2

Sensation	Frequency	(0-6)	Severity	(0-6)
	Pre	1 wk Post	Pre	1 wk Post
Burning	0	0	0	0
Tight	1	0	2	0
Dry	1	0	2	0
Aching	0	0	0	0
Tickling	0	0	0	0
Sore	0	0	0	0
Irritable	1	0	2	0
Lump in throat	0	0	0	0

Table 17: GRBAS scale for patient 2

	Pre	Post	1 wk Post
G (Grade of hoarseness)	2	2	1
R (Roughness)	1	2	0
B (Breathiness)	2	2	1
A (Asthenia)	1	1	0
S (Strain)	0	1	0

The GRBAS scale showed an increase in roughness, breathiness and strain immediately post treatment. This could possibly be attributed to post treatment discomfort but values given one week post treatment indicated significant improvement across all parameters.

As indicated previously for patient 2, F_0 and VTI values showed improvement while RAP, Shim and NHR worsened. In contrast the VTD scale and GRBAS scale results one week post treatment were all positive. This shows that there is no useful correlation between objective (MDVP) and subjective (VTD and GRBAS) measures for this patient.

4.2.2 Patient 3

Table 18: MDVP results for patient 3

Patient	Parameter	Pre	Post	1wk Post	Norm	Unit	STD(f)	Thresh
3	F_0	241.917	116.344	243.062	243.973	Hz	27.457	
	RAP	0.687	1.041	2.007	0.378	%	0.214	0.68
	Shim	4.858	9.299	14.38	1.997	%	0.791	3.81
	NHR	0.121	0.161	0.247	0.112		0.009	0.19
	VTI	0.049	0.069	0.057	0.046		0.012	0.061

RAP, Shim, NHR and VTI all increased immediately post treatment. RAP, Shim and

NHR increased further in the readings taken one week post treatment while VTI readings dropped. F_0 readings decreased significantly immediately post treatment and then returned close to the initial value when tested one week post treatment.

Table 19: VTD scale for patient 3

Sensation	Frequency	(0-6)	Severity	(0-6)
	Pre	1 wk Post	Pre	1 wk Post
Burning	3	4	4	4
Tight	4	3	6	5
Dry	6	6	6	6
Aching	4	4	6	6
Tickling	2	2	2	4
Sore	5	6	6	6
Irritable	6	5	4	5
Lump in throat	6	4	6	4

The VTD scale showed a decrease in both severity and frequency of tightness as well as for the feeling of a lump in the throat. There was a decrease in frequency of irritability but an increase in severity. An increase in frequency of burning and soreness and an increased severity of ticking and irritability was reported.

Table 20: GRBAS scale for patient 3

	Pre	Post	1 wk Post
G (Grade of hoarseness)	3	1	3
R (Roughness)	3	3	3
B (Breathiness)	0	1	0
A (Asthenia)	1	1	2
S (Strain)	2	2	2

GRBAS scale indicated a decrease in hoarseness but an increase in breathiness post treatment. Readings taken one week post treatment showed an increase in asthenia when compared to the initial reading.

In patient 3, all MDVP parameters moved further away from their norms immediately post treatment and this movement increased further one week post treatment with the exception of F_0 and VTI. Only F_0 improved when compared to the pre-treatment reading. Inconsistent readings were visible on the VTD scale with increases and decreases in both severity and frequency of multiple parameters and in the case of irritability, the frequency decreased but the severity increased making it inconclusive.

The GRBAS scale was also inconsistent with hoarseness improving but breathiness worsening immediately post treatment. One week post treatment showed that only asthenia had worsened compared to the initial readings which could correlate with the negative movement of MDVP values for the same period.

4.2.3 Patient 5

Table 21: MDVP results for patient 5

Patient	Parameter	Pre	Post	1wk Post	Norm	Unit	STD(f)	Thresh
5	F_0	221.237	251.184	N/A	243.973	Hz	27.457	
	RAP	0.763	0.569	N/A	0.378	%	0.214	0.68
	Shim	5.762	4.436	N/A	1.997	%	0.791	3.81
	NHR	0.147	0.128	N/A	0.112		0.009	0.19
	VTI	0.064	0.079	N/A	0.046		0.012	0.061

MDVP showed an increase in F_0 and VTI and a decrease in RAP, Shim and NHR immediately post treatment. The patient did not return for measurements one week post treatment so values for comparison were not available.

Table 22: VTD scale for patient 5

Sensation	Frequency	(0-6)	Severity	(0-6)
	Pre	1 wk Post	Pre	1 wk Post
Burning	0	N/A	0	N/A
Tight	0	N/A	0	N/A
Dry	3	N/A	4	N/A
Aching	0	N/A	0	N/A
Tickling	0	N/A	0	N/A
Sore	2	N/A	3	N/A
Irritable	2	N/A	3	N/A
Lump in throat	0	N/A	0	N/A

Patient non-attendance resulted in no VTD measurements being taken one week post treatment.

Table 23: GRBAS scale for patient 5

	Pre	Post	1 wk Post
G (Grade of hoarseness)	2	3	N/A
R (Roughness)	3	2	N/A
B (Breathiness)	1	3	N/A
A (Asthenia)	0	0	N/A
S (Strain)	1	2	N/A

GRBAS readings for this patient showed an increase in hoarseness, breathiness and strain but a decrease in roughness immediately post treatment.

All MDVP parameters for patient 5 moved closer to normal values post treatment with the exception of VTI. One could assume that these objective measures could indicate an improvement in voice quality but the results do not correlate with the GRBAS readings which were mostly negative with the exception of roughness. This makes the results inconsistent and inconclusive.

4.3: Experimental participant results versus control participant results

Table 24: Movement of MDVP parameters relative to pre-treatment readings

Patient	F_0 Post	F_0 1 wk Post	RAP Post	Rap 1wk Post	Shim Post	Shim 1 wk Post	NHR Post	NHR 1 wk Post	VTI Post	VTI 1 wk Post
1 (LMT+CSM)	↑	↑	↑	↓	↓	↓	↓	↓	↑	↓
2 (LMT)	↑	N/A	↑	N/A	↑	N/A	↑	N/A	↑	N/A
3 (LMT)	↓	↑	↑	↑	↑	↑	↑	↑	↑	↑
4 (LMT+CSM)	↓	N/A	↓	N/A	↓	N/A	↓	N/A	↓	N/A
5 (LMT)	↑	N/A	↓	N/A	↓	N/A	↓	N/A	↑	N/A
6 (LMT+CSM)	↓	↑	↑	↑	↑	↑	↑	↓	↓	↑

The above table indicates whether MDVP parameter values increased (↑) or decreased (↓) in relation to values recorded pre-treatment or if data was unavailable (N/A).

Table 25: Effects of movement of MDVP readings

Patient	Fo Post	Fo 1wk Post	RAP Post	Rap 1wk Post	Shim Post	Shim 1 wk Post	NHR Post	NHR 1 wk Post	VTI Post	VTI 1 wk Post
1 (LMT+CSM)	I	I	D	I	I	I	I	I	D	I
2 (LMT)	I	N/A	D	N/A	D	N/A	D	N/A	I	N/A
3 (LMT)	D	I	D	D	D	D	D	D	D	D
4 (LMT+CSM)	D	N/A	I	N/A	I	N/A	I	N/A	D	N/A
5 (LMT)	I	N/A	I	N/A	I	N/A	I	N/A	D	N/A
6 (LMT+CSM)	D	I	I	I	D	D	D	I	D	D

- I = Improved. Values were closer to normal values when compared to pre-treatment readings indicating improvement.
- D = Decreased. Values were further away from normal values when compared to pre-treatment readings indicating no improvement.
- N/A = Data was either corrupted (1 case) or patients did not return for measurements to be taken one week post treatment (2 cases).

Twenty two out of sixty parameters indicated improvement (36.66%), fifteen of which were in the LMT+CSM participants and seven were in the LMT participants. Twenty three out of sixty parameters showed a decline (38.33%), ten of which were in the LMT+CSM participants and thirteen were in the LMT participants. Data was either corrupt or unavailable for fifteen out of sixty parameters (15%), five of which were in the LMT+CSM participants and ten were in the LMT participants. Due to the larger number of unavailable readings in the LMT participants, it was not possible to conclude whether or not LMT+CSM was superior over LMT in improving voice parameters as all participants showed a mix of improved and decreased values over the various parameters. However, even with less available data, the control participants recorded a higher amount of declining values indicating a more negative impact on phonation over that of the experimental participants.

Table 26: VTD scale summary

Patient	Measure	Burning	Tight	Dry	Aching	Tickling	Sore	Irritable	Lump in throat
1	Frequency	–	↓	↓	↑	–	↑	↑	–
(LMT+CSM)	Severity	–	–	–	↑	–	↑	↑	–
2	Frequency	–	↓	↓	–	–	–	↓	–
(LMT)	Severity	–	↓	↓	–	–	–	↓	–
3	Frequency	↑	↓	–	–	–	↑	↓	↓
(LMT)	Severity	–	↓	–	–	↑	–	↑	↓
4	Frequency	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(LMT+CSM)	Severity	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	Frequency	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(LMT)	Severity	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	Frequency	–	–	↓	–	↓	–	↓	
(LMT+CSM)	Severity	↑	↓	↓	↑	↓	↑	↓	↑

- ↑ = Increase in frequency/severity when compared to pre-treatment values.
- ↓ = Decrease in frequency/severity when compared to pre-treatment values.
- \- = No change in frequency/severity when compared to pre-treatment values.
- N/A = Data unavailable as patients did not return for measurements one week post treatment.

Twenty nine out of ninety six (30.20%) VTD scale readings exhibited no change in severity/frequency of symptoms. Fourteen readings (14.58%) showed an increase in severity/frequency of symptoms and twenty readings (20.83%) showed a decrease. Of the fourteen increased readings, ten were in the LMT+CSM participants while four were in the LMT participants. Nine of the decreased readings were in the LMT+CSM participants while eleven were in the LMT participants. While the decrease in severity/frequency of VTD was almost equal amongst all the participants there was a visible difference between the increases in severity/frequency. The LMT+CSM participants produced a far greater increase in severity/frequency of VTD which could perhaps be attributed to post manipulation discomfort which is a common side effect of cervical manipulation (Cagnie, et al 2004; Senstad, et al 1996).

Data was unavailable for thirty two out of ninety six readings (33.33%), however the unavailable data was for one LMT+CSM patient and for one LMT patient which would cancel each other out and therefore not affect the perceived results mentioned above.

Table 27: GRBAS scale summary

Patient	Measure	G	R	B	A	S
1	Post	–	↓	–	–	↑
(LMT+CSM)	1 wk Post	–	↓	–	–	↑
2	Post	–	↑	–	–	↑
(LMT)	1 wk Post	↓	↓	↓	↓	–
3	Post	↓	–	↑	–	–
(LMT)	1 wk Post	–	–	–	↑	–
4	Post	↑	–	↓	–	↓
(LMT+CSM)	1 wk Post	N/A	N/A	N/A	N/A	N/A
5	Post	↑	↓	↑	–	↑
(LMT)	1 wk Post	N/A	N/A	N/A	N/A	N/A
6	Post	↑	↑	–	↑	↑
(LMT+CSM)	1 wk Post	–	–	–	–	–

- ↑ = Increase in values when compared to pre-treatment readings indicating a more negative perception of phonation.

- ↓ = Decrease in values when compared to pre-treatment readings indicating a more positive perception of phonation.
- - = No change in values when compared to pre-treatment assessment.
- N/A = Data unavailable as patients did not return for measurements one week post treatment.

Twenty six out of sixty readings (43.33%) showed no change, ten (16.66%) indicated a decrease in value or a perceived improvement in phonation while fourteen (23.33%) exhibited an increase in value or a perceived worsening of the voice. Four of the improved readings were in the LMT+CSM participants and six were in the LMT participants, showing a slightly greater tendency for improvement in the LMT group. The values that worsened were equal across all participants and were overall greater than the improvement results.

Data was unavailable for the one week post period for one LMT+CSM patient as well as for one LMT patient, therefore this should not affect the perceived results above as the data was equally unavailable in both groups.

Chapter 5: General Discussion and Conclusion

This research aimed to show whether or not CSM and LMT would have a more positive effect on voice quality in MTD patients than that of LMT alone. Previous research has shown that LMT is an effective form of treatment for patients with MTD (Aronson et al, 1990; Roy et al, 1996; Roy et al, 1997; Roy et al, 2009; Mathieson et al, 2007; Mathieson, 2011; Lieberman et al, 2005; Dromey et al, 2008) and this research hoped to show that CSM could prove to be a useful adjunct in the treatment of this complex disorder.

It proposed that a decrease in muscular inhibition of the extrinsic laryngeal muscles achieved through the restoration of normal muscle length-tension relationships as well as improved neurological input, would result in the correct positioning of the larynx with the removal of any restrictions in movement of the vocal apparatus thus improving phonation. It also aimed to highlight the permanent or temporary nature of any changes in phonation in these patients and the inclusion of CSM as an effective modality in the multidisciplinary treatment of MTD.

The results from this study were extremely inconsistent and inconclusive. In multiple instances there were both positive and negative changes in the objective data (MDVP) and in the subjective data (VTD and GRBAS) for each patient. The inconsistency of the data made it difficult to draw any conclusion as to the improvement of the patient's voice as the individual parameter readings of each test often contradicted each other. There was also no correlation between the three scales and the inconsistency of the results was seen in both the experimental and the control participants.

5.1: Limitations

The limitations of this study were the small sample size, the high level of patient non-compliance, the subjective nature of examination and treatment of the patient and of the GRBAS scale, the fact that patients only had one treatment session and that all the patients treated were diagnosed with secondary MTD.

The prevalence of MTD in the South African population was greatly over estimated as only six patients with the condition presented to our practice over the two year period allocated for this research. This small sample size makes it impossible to generalise the findings to the larger population of MTD sufferers (Brink et al, 2012). This was further compounded by the high rate of patient non-compliance when it came to returning for measurements one week post treatment. This resulted in the inability to draw any conclusions as to whether any changes that presented, were permanent or temporary. This study was also limited to only one treatment session for each patient to align it with previous research and although the aim was to assess if there was any immediate change in phonation post treatment, greater changes and perhaps patterns of changes may have been evident only after multiple treatments as seen in previous studies (Van Lierde et al, 2004).

LMT has been shown to have significant variation amongst practitioners (Mathieson, 2011) and as a result it is difficult to ascertain whether or not the technique used by the chiropractor in this research in both the examination and treatment of the patients, was the ideal version of the technique to elicit the positive changes in phonation that were seen in previous studies (Aronson et al, 1990; Roy et al, 1996; Roy et al, 1997; Roy et al, 2009; Mathieson et al, 2007; Lieberman et al, 2005; Dromey et al, 2008).

Although the GRBAS scale is regarded as a valid and reliable test for assessing voice quality (Nemr, et al. 2012; Carding, et al. 2009; De Bodt, et al. 1997), it is highly subjective and should have been further corroborated by additional GRBAS assessments of the same samples but from multiple speech therapists.

All patients in this study were diagnosed with secondary MTD and the underlying pathology could have been responsible for some, if not all, of the inconsistencies in the data obtained.

5.2: Conclusions and recommendations

Although this research provides a proposed working model into the possible effects of CSM on phonation, the small sample size does not allow for any conclusions to be drawn. As a result a significant increase in sample size is recommended and also perhaps the inclusion of other voice disorders and not solely MTD. If a new study was to be conducted on MTD alone but on a larger scale, it would be advisable to attempt to limit the participants to those diagnosed only with primary MTD as any underlying pathology may otherwise impact the results.

It would also be advisable to conduct the study on the effects of CSM on patients with voice disorders without the inclusion of LMT to accurately assess whether CSM is a worthwhile stand-alone modality to be used in a multidisciplinary approach in the treatment of voice disorders.

Although the individual patient results in this study were described in detail, one was unable to detect any patterns or trends in vocal changes post treatment further indicating the need for an increased sample size. Patient non-compliance in the stage one week post treatment could possibly be minimised by including a second treatment session to entice the patient to return for measurements, further allowing for more data to be collated to determine the permanence of any vocal changes.

Due to the inconsistencies in the data it is not possible to conclude whether CSM leads to a decrease in inhibition of the suprahyoid and infrahyoid musculature and the diaphragm, resulting in a lowering of the larynx and improved phonation. Multiple treatments could be performed on each patient instead of one which might result in more consistent readings which may then unearth patterns of changes in phonation.

After an intensive literature review, the research also underscored the need for more studies into the effects of CSM on phonation as there are currently no studies in this regard. It also supports the need for an increase in blinded, controlled and randomised studies into the effects of LMT on voice quality.

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Appendix 1: WITS ethical clearance certificate

R14/49 Dr Robin Mark Maris

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M160812

NAME: **(Principal Investigator)**	Dr Robin Mark Maris
DEPARTMENT:	Speech Audiology and Pathology Private Practice of Dr LP Maron at The voice and Swallowing Centre, Parktown, Johannesburg
PROJECT TITLE:	The Effects of Cervical Spine Manipulation on Phonation in Patients with Muscle Tension Dysphonia
DATE CONSIDERED:	26/08/2016
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Prof Heila Jordaan
APPROVED BY:	Professor P Cleaton-Jones,Chairperson, HREC (Medical)
DATE OF APPROVAL:	28/10/2016

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 301, Third Floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in August and will therefore be due in the month of August each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature ____________ Date ____________

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix 2: Vocal Tract Discomfort Scale

Patient identifier:_____________________ **Date:**_______________________________	**Frequency of sensation/symptom** Never sometimes often always |___|____|____|____|____|____| 0 1 2 3 4 5 6	**Severity of sensation/symptom** Never sometimes often always |___|____|____|____|____|____| 0 1 2 3 4 5 6
1. Burning	0 1 2 3 4 5 6	0 1 2 3 4 5 6
2. Tight	0 1 2 3 4 5 6	0 1 2 3 4 5 6
3. Dry	0 1 2 3 4 5 6	0 1 2 3 4 5 6
4. Aching	0 1 2 3 4 5 6	0 1 2 3 4 5 6
5. Tickling	0 1 2 3 4 5 6	0 1 2 3 4 5 6
6. Sore	0 1 2 3 4 5 6	0 1 2 3 4 5 6
7. Irritable	0 1 2 3 4 5 6	0 1 2 3 4 5 6
8. Lump in throat	0 1 2 3 4 5 6	0 1 2 3 4 5 6

Appendix 3: Participant Information Sheet

Speech – Language Pathology & Audiology. School of Human and Community Development

Private Bag 3, Wits 2050, South Africa

Tel: +27 11 717 4500/2/3/4

Fax: +27 11 717 4559

Dear Sir/Madam

Good day. My name is Robin Maris, I am a chiropractor currently completing my master's degree at The University of the Witwatersrand. To do this I am conducting a study titled 'The Effects of Cervical Spine Manipulation and Laryngeal Manipulative Therapy on Phonation in Patients with Muscle Tension Dysphonia'.

This document is an information sheet that will describe the reasons the study is being done, how it will be conducted and what will be required of you should you be willing to participate. If you have any questions regarding the information sheet I will be readily available to answer them and provide any further clarification should it be required.

After reading the form I will request a decision from you as to whether or not you would like to participate in my study. If you agree, you will then be required to sign a consent form confirming your wish to participate. You will also receive a copy of this form for your records.

The aim of my research is to determine whether cervical spine manipulation and laryngeal manipulative therapy are more effective in improving voice in patients with muscle tension dysphonia than laryngeal manipulative therapy on its own.

Laryngeal manipulative therapy is a technique used to relax the muscles that move your larynx allowing it to move more freely and improve your voice. Cervical spine manipulation is a technique used to correct possible misalignment of the vertebrae in your neck to prevent any compression of the nerves that supply the muscles that move your larynx. The compression of these nerves negatively affects the messages being sent from your brain to these muscles and vice versa which can impact your voice. The abnormal position of the vertebrae in your neck can also over-shorten or over-stretch some of the muscles that control the movement your larynx which may alter your voice. Repositioning these vertebrae may return these muscles to their optimal length which could improve your voice.

I hope to improve the quality and/or strength of your voice through the treatment that I will administer and then determine which form the treatment is more beneficial. This study will hopefully provide us with another modality to be used when treating other patients suffering with muscle tension dysphonia.

I will be doing this research under the guidance of a supervisor, Professor Heila Jordaan and we would like to invite you to take part.

If you decide to take part it will mean that you agree to have your voice recorded and to be treated by myself using cervical spine manipulation and/or laryngeal manipulative therapy at the Voice and Swallowing Centre in Parktown, Johannesburg South Africa.

The benefits of participating in this study will be a possible reduction in vocal tract discomfort and an improved quality and/or strength of your voice and also in the future, hopefully help others in the same situation.

Minor adverse events following cervical spine manipulation are relatively common, non-serious and transient whereas the risk of a serious adverse event, immediately or up to seven days post treatment is recorded as low to very low.

Minor adverse events are classified as a worsening of presenting symptoms or onset of new symptoms.

Headache, stiffness, local discomfort, radiating discomfort and fatigue are commonly experienced and the symptoms usually presented within four hours and resolved in the preceding twenty four hours. Fainting/dizziness/light headedness as well as myalgia and radiculopathy are rare but possible side effects of cervical spine manipulation (Thiel, Bolton, Docherty, Portlock 2007).

Fractures, joint dislocations, prolapsed discs, ligament sprains or tears, muscular strains or tears, Brown-Sequard syndrome, chronic radiculopathy, chronic myelopathy, vertebral artery occlusion, vertebral or carotid artery dissection and stroke are major adverse events that have been rarely associated with cervical spine manipulation.

The complication rate from cervical spine manipulation is estimated to be between **5 and 10 per 10 million** manipulations.

Most adverse events that were reported following cervical spine manipulation involved manipulation with a rotational movement of the cervical spine. The adjustment that will be utilised in this study is a modified version of the Cervical Break technique which will only employ a lateral flexion movement when manipulating. No rotational type manipulation will be used in the interest of patient safety.

A careful history and physical examination will be conducted to determine whether or not you are at risk. If it is determined that you are unsuitable for such treatment you will unfortunately not be able to participate in the study.

Your participation in this study is voluntary and all of your information will be kept confidential. You will not be identified in the research report and only the supervisor and I will have access to your information. Your recordings and forms will be kept in a secure place by the University of the Witwatersrand for five years after which they will be destroyed.

In this study you have the right to:

- Withdraw from the study at any stage without any negative consequences
- Withhold any of the recorded information from me
- Contact me at any time with concerns or questions
- Contact the Human Research Ethics Committee (Medical) chairperson should you have any concerns or complaints about the study or me as the researcher

A summary of the results of the study will be made available on request.

For any further information you can contact me on 072 777 1771 or via email on maris@discoverymail.co.za

If you choose to participate in this research please fill in your details on the form below.

Appendix 4: Informed Consent to be recorded and treated

I_____________________________________ (NAME OF PARTICIPANT), the undersigned, agree to volunteer in this study in writing. I understand that I will have my voice recorded and be treated with cervical spine manipulation and/or laryngeal manipulative therapy by Dr Robin Maris for his study on the effects of cervical spine manipulation and/or laryngeal manipulative therapy on phonation in patients with muscle tension dysphonia.

I understand that this research is for a Master's degree at the University of the Witwatersrand and my participation is voluntary. I also understand that my voice will be recorded for later use and that I can hold back any recorded material from the researcher should I wish to. These recording may be used in future research. I am aware that I may withdraw from the study at any stage, that no identifiable information will be in the report and that my responses will remain confidential.

I understand the risks associated with the type of treatment used in this study and that I may be excluded from the study after being examined if I am considered at risk. I am aware that I may leave the study at any point without any negative consequences to myself and that Robin is available at any stage should I have questions regarding the study.

I have read or spoken about this document and the information sheet and I recognise Robin Maris as the primary researcher for this project and agree to participate in his study.

____________________ ________________________

Participant Name (Print) Participant Signature

____

Date

____________________ ________________________

Witness Name (Print) Witness Signature

____

Date

Appendix 5: GRBAS Scale

GRBAS Scale

Protocol No.____________________ Voice No. _____________________ Date____ / ____ / ____

G____ R____ B____ A____ S____

Appendix 6

CERVICAL SPINE REGIONAL EXAMINATION

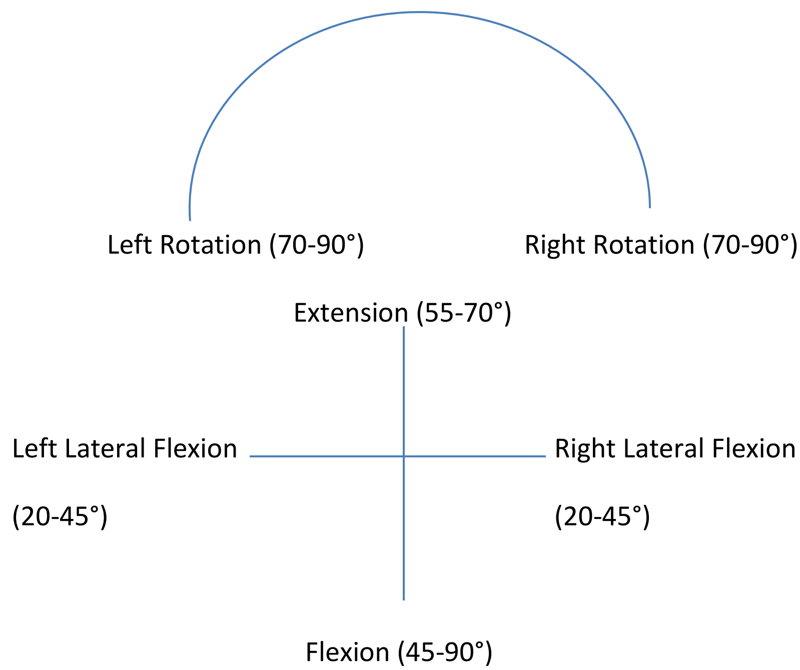
Date: ____________________________

Patient: __________________________

Research No. ______________________

OBSERVATION
Posture
Size
Swellings
Scars
Discolouration
Hairline
Bony and soft tissue contours
Shoulder level
Muscle spasm
Facial expression

RANGE OF MOVEMENT



PALPATION
Lymph Nodes
Trachea
Thyroid Gland
Pulses
Tenderness
Muscle Tone
Active Myofascial Trigger Points

VASCULAR EXAMINATION	
Blood Pressure (Left)	(Right)
Carotids (Left)	(Right)
Subclavian Arteries (Left)	(Right)
Wallenberg's Test (Left)	(Right)

NEUROLOGICAL EXAMINATION		
DERMATOMES	**LEFT**	**RIGHT**
C2		
C3		
C4		
C5		
C6		
C7		
C8		
T1		
MYOTOMES		
Neck Flexion C1/2		
Lat Neck Flexion C3		
Shoulder Elevation C4		
Shoulder Abduction C5		
Elbow Flexion C5		
Elbow Extension C7		
Elbow Flexion @ 90 Degrees C6		
Forearm Pronation C6		
Forearm Supination C6		
Wrist Extension C6		
Wrist Flexion C7		
Finger Flexion C8		
Finger Abduction T1		
Finger Adduction T1		
REFLEXES		
Biceps C5/6		
Brachioradialis C6		
Triceps C7		

ORTHOPAEDIC EXAMINATION
Doorbell Sign
Max. Cervical Compression
Spurling's Manouvre
Lateral Compression (Jackson's) Test
Kemp's Test
Cervical Distraction
Shoulder Abduction Test
Shoulder Depression Test
Dizziness Rotation Test
Lhermitte's Sign
O' Donoghue Manouvre
Brachial Plexus Tension
Carpal Tunnel: *Tinel's Sign* *Phalen's Test*
TOS: *Halstead's Test* *Adson's Test* *Eden's (Traction) Test* *Hyperabduction/Wright's Test (Pec Minor)* *Costoclavicular Test*

MOTION PALPATION														
JOINT PLAY		LEFT						RIGHT					JOINT PLAY	
P/A	LAT	FLE	EXT	LF	AR	PR		FLE	EXT	LF	AR	PR	P/A	LAT
							C1							
							C2							
							C3							
							C4							
							C5							
							C6							
							C7							
							T1							
							T2							
							T3							
							T4							