The relationship between neck pain and dysfunction, and breathing outcomes

By Sarah Stephen

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DECLARATION

I, Sarah Stephen, declare that the work contained in this dissertation is my own work, except to the extent indicated in the acknowledgement sections.

This dissertation is being submitted for a degree of Masters in Physiotherapy, at the University of the Witwatersrand, Johannesburg, South Africa.

This work has not been submitted for any other degree or examination in this or any other university.

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ABSTRACT

Background

Neck pain is common and has a high rate of chronicity. A relationship between neck pain and breathing exists and is influenced by biomechanical, biochemical and psychological factors. The aim of the study was to investigate this relationship, and how perceived stress and muscle activity of the scalene and sternocleidomastoid muscles during breathing influences it.

Method

This cross-sectional study consisted of 49 participants with neck pain and 49 matched controls. Both groups completed the Nijmegen Questionnaire (NQ), Self-Evaluation of Breathing Questionnaire (SEBQ) and Perceived Stress Scale (PSS). Deep neck flexor strength, respiratory rate, thoracic expansion, Breath Hold Time (BHT) and surface electromyography (sEMG) of the sternocleidomastoid and scalene muscles during breathing were also assessed. The numeric rating scale (NRS) and neck disability index (NDI) assessed pain intensity and neck disability in the neck pain group only.

Results

Participants with neck pain reported mild pain and disability, and had reduced deep neck flexor strength, higher NQ and higher SEBQ scores than participants without neck pain. Respiratory rate, thoracic expansion, BHT, sEMG and PSS were similar between the groups. The NQ and SEBQ correlated moderately with NDI and PSS scores. The SEBQ correlated fairly with NRS. Respiratory rate correlated fairly with NDI. Muscle activity did not correlate to any other measure.

Conclusion

Self-reported symptoms of dysfunctional breathing, assessed using the NQ and SEBQ, were more present in participants experiencing neck pain than participants without neck pain. The NQ and SEBQ were associated with neck disability as well as with perceived stress.

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LIST OF ABBREVIATIONS

BHT: Breath Hold Time

BMI: Body mass index

bpm: breaths per minute

CCFT: Cranio-Cervical Flexion Test

CO_2: Carbon Dioxide

CTMT: Cloth Tape Measure Technique

EMG: Electromyography

ERV: Expiratory Reserve Volume

FEV_1: Forced Expiratory Volume in one second

FVC: Forced Vital Capacity

MVV: Maximum Voluntary Ventilation

NDI: Neck Disability Index

NQ: Nijmegen Questionnaire

NRS: Numeric Rating Scale

PEF: Peak Expiratory Flow

PSS: Perceived Stress Scale

SEBQ: Self-Evaluation of Breathing Questionnaire

sEMG: Surface Electromyography

VC: Vital Capacity

LIST OF KEY TERMS

COSTO-DIAPHRAGMATIC BREATHING PATTERN: A breathing pattern where lower thoracic movement is greater than upper thoracic movement during inhalation.

DYSFUNCTIONAL BREATHING: When there are changes in breathing pattern that impair the normal functioning of breathing, and result in undesired respiratory or non-respiratory symptoms.

HYPERVENTILATION: A type of dysfunctional breathing where the rate or depth of breathing exceeds the body's metabolic requirements.

NUEROMUSCULAR DYSFUNCTION: When a muscle, or group of muscles, do not perform optimally. This involves the related muscles and their innovating nerves.

UPPER-COSTAL BREATHING PATTERN: A breathing pattern where upper thoracic movement is greater than lower thoracic movement during inhalation.

1 INTRODUCTION AND SCOPE OF THE DISSERTATION

1.1 Background

Neck pain is common with high levels of recurrence and chronicity (Hogg-Johnson et al., 2008; Blanpied et al., 2017), increasing global prevalence (Hurwitz et al., 2018b), and generally poor prognosis (Hush et al., 2011). The strongest risk factors for the development of neck pain are psychosocial factors, a history of previous neck pain and the female sex (Blanpied et al., 2017; Kim et al., 2018). Prognosis is influenced by many factors including age, sex, previous neck pain and psychosocial factors (Carroll et al., 2008; Cohen, 2015).

The neck has many connections with the thorax including fascial and muscular connections (Drake et al., 2010). The scalene and sternocleidomastoid muscles are situated in the neck and are involved in upper thoracic stabilisation or expansion during inspiration, especially with increased respiratory demand (Pryor and Prasad, 2008; Drake et al., 2010). The diaphragm is the main muscle of inspiration and, if dysfunctional, could lead to changes in breathing patterns (Hruska, 1997; Courtney, 2009; Chaitow et al., 2014b) as well as reduced spinal stability (Clifton-Smith, 2014).

When there are changes in breathing pattern that impair the normal functioning of breathing, and result in undesired respiratory or non-respiratory symptoms, it is termed dysfunctional breathing (Barker et al., 2018; Boulding et al., 2016; Courtney, 2016). Dysfunctional breathing is a multidimensional problem which has biomechanical, biochemical and psychological components (Chaitow et al., 2014b; Courtney, 2016).

The biomechanical aspect of breathing refers to the way in which the ribcage and muscles influence breathing (Courtney, 2016), and includes lung function, breathing patterns, muscle dysfunction and respiratory strength. People with neck pain are more likely to have reduced respiratory function and respiratory strength (Kapreli et al., 2009; Dimitriadis et al., 2013a; Dimitriadis et al., 2014; Wirth et al., 2014; López-de-Uralde-Villanueva et al., 2018) as well as breathing kinematic changes such as "faulty breathing", upper-costal breathing and reduced thoracic expansion (Perri and Halford, 2004; Halim et al., 2016). An upper-costal breathing pattern may be due to a dysfunctional diaphragm and lead to overuse of the parasternal and neck accessory muscles (Hruska, 1997; Courtney, 2009; Gilbert, 2014b).

People with neck pain demonstrate increased activation of the sternocleidomastoid and scalene muscles, and reduced activation of the deep neck flexors for the same task (Jull et al., 2004), which may be related to pain (Cagnie et al., 2011). Some studies have reported that people who breathe with an upper-costal breathing pattern have an increase in muscle activity of superficial neck muscles during a Cranio-Cervical Flexion Test (CCFT) than those who breathe with a costo-diaphragmatic pattern (Cagnie et al., 2008; Koh and Jung, 2013; Valenzuela et al., 2017). The diaphragm has also been reported to have increased muscle activity during an upper-costal breathing pattern compared with a costo-diaphragmatic breathing pattern. (Celhay et al., 2015; Miralles et al., 2016).

The diaphragm as well as the neck muscles are involved not only in respiration, but also in postural stability (Hodges et al., 2001; Stapley et al., 2006; Clifton-Smith, 2014; Kolar et al., 2014). Furthermore, the abdominal muscles are needed for effective diaphragm functioning (Hruska, 1997; Rychnovský and Pivec, 2009). Therefore, weakness in the diaphragm, abdominal muscles or neck muscles may contribute toward respiratory weakness as well as spinal instability. This is confirmed by correlations of neck flexor and extensor strength with respiratory strength in participants with neck pain (Dimitriadis et al., 2013a; López-de-Uralde-Villanueva et al., 2018). Posture also influences respiration with there being reports of reduced respiratory strength, respiratory function and thoracic expansion in people with a head forward posture (Kapreli et al., 2009; Halim et al., 2016; Han et al., 2016; Zafar et al., 2018), a common posture observed in association with neck pain (Yip et al., 2008; Silva et al., 2009; Nejati et al., 2014).

Biochemical influences of breathing include the effects of hyperventilation, often resulting in hypocapnia and a respiratory alkalosis (Gardener, 1996; Pryor and Prasad, 2008; Chaitow et al., 2014a). Hypocapnia is common in people with chronic neck pain (Dimitriadis et al., 2013b) and those with chronic neck and back pain (Mclaughlin et al., 2010). Hyperventilation and resultant hypocapnia may be a coping strategy to pain (Wilhelm et al., 2001; Terekhin and Forster, 2006). However, it may also contribute towards musculoskeletal dysfunction as a respiratory alkalosis is associated with muscle tension, muscle spasm, muscle ischemia and resultant musculoskeletal pain (Schleifer et al., 2002). This may be related to the loss of calcium in the urine that occurs with metabolic compensation following a respiratory alkalosis (Chaitow et al., 2014a). Breathing changes such as slow deep breathing, breath-holding as well as hyperventilation all have pain modulating effects (Terekhin and Forster, 2006; Zautra et al., 2010; Busch et al., 2012; Reyes del Paso et al., 2015). Therefore, hyperventilation may be a response to pain, but the resultant hypocapnia and respiratory alkalosis could increase musculoskeletal dysfunction if not corrected.

Hyperventilation and other breathing changes may also be as a result of psychological factors such as anxiety (Gardner, 1996; Hegel and Fergusson, 1997; Wilhelm et al., 2001; Jack et al., 2003; Jack et al., 2004; Meuret and Ritz, 2010; Agahe et al., 2012; Boulding et al., 2016). Anxiety disorders and depression are both associated with increased levels of neck pain (Demyttenaere et al., 2007; Blozik et al., 2009; Dimitriadis et al., 2015; López-de-Uralde-Villanueva et al., 2018). Feelings of anxiety are likely to cause an increase in sympathetic activity, leading to changes in breathing rate and depth as well as an increase in muscle tension (Wilhelm et al., 2001; Chaitow et al., 2014a). If this response persists beyond the stressful episode, or for a prolonged length of time, this may lead to adverse emotional, physical and immunological effects (Sikter et al., 2009; Chaitow et al., 2014a; Barker and Everard, 2015; Vidotto et al., 2019).

Multiple subjective and objective assessment tools are recommended in the evaluation of dysfunctional breathing (Bradley, 2014; van Dixhoorn and Folgering, 2015; Boulding et al., 2016; Vidotto et al., 2019). Outcome measures used in the current study that evaluated neck pain and neck dysfunction included the Numeric Rating Scale (NRS) for pain, the Neck Disability Index (NDI) for neck disability, and the CCFT for evaluating deep neck flexor strength, endurance and control. Outcome measures that evaluated breathing included the respiratory rate as well as the Cloth Tape Measure Technique (CTMT) for thoracic expansion, the Nijmegen Questionnaire (NQ), the Self-Evaluation of Breathing Questionnaire (SEBQ) and Breath Hold Time (BHT). Surface Electromyography (sEMG) was used to determine muscle activity of the scalene and sternocleidomastoid muscles during quiet and deep breathing for those with and without neck pain. The Perceived Stress Scale (PSS) was used to determine perceived stress, evaluating the psychological dimension of neck pain and dysfunctional breathing.

1.2 Problem statement

Neck pain is a common complaint in the general population and levels of recurrence and chronicity are high (Hogg-Johnson et al., 2008; Blandpied et al., 2017). Neck pain has a high economic burden due to health costs and time away from work, and is rated the fourth leading cause of disability (Hoy et al., 2010; Blandpied et al., 2017). Changes in respiratory function, respiratory strength, CO_2 levels, thoracic expansion and breathing pattern have been reported to be more prevalent in participants with neck pain, and relate to neck dysfunction (Perri and Halford, 2004; Kapreli et al., 2009; Dimitriadis et al., 2013a; Dimitriadis et al., 2013b; Dimitriadis et al., 2014; Wirth et al., 2014; Halim et al., 2016; López-de-Uralde-Villanueva et al., 2018). It has been recommended that breathing assessment may be beneficial in the assessment and management of chronic neck pain (Dimidriadis et al., 2016). However, the inclusion of breathing has not been included in the recommended management for acute or chronic neck pain (Blanpied et al., 2017; Bier et al., 2018; Parikh et al., 2019). Therefore, there is a need for more research to be done to confirm if assessment and treatment methods addressing breathing is helpful in the management of neck pain.

Furthermore, if breathing assessment is included in the management of neck pain, it is unclear what assessment methods are most relevant. Previous studies have assessed maximum inspiratory and expiratory pressures, spirometry, capnography, CTMT and breathing pattern recognition in participants with neck pain (Kapreli et al., 2009; Dimitriadis et al., 2013a; Dimitriadis et al., 2013b; Dimitriadis et al., 2014; Wirth et al., 2014; Halim et al., 2016; López-de-Uralde-Villanueva et al., 2017). To the researcher’s knowledge, there are no studies that assess breathing in participants experiencing neck pain, using subjective and objective measures that are available at minimal cost addressing the multidimensional nature of breathing.

Reduced strength and endurance of the deep neck flexors is common in people experiencing neck pain (Chiu et al., 2005; O’Leary et al., 2007; Jull et al., 2008). The role of deep neck flexor strength and endurance in people experiencing neck pain in relation to other respiratory outcomes is unknown.

There have been reports of increased sternocleidomastoid and scalene muscle activity in participants with neck pain during rest, clenching, swallowing and while performing the CCFT compared to controls (Santanter et al., 2000; Falla et al., 2004; Jull et al., 2004; Cagnie et al., 2011). An upper-costal breathing pattern may also result in increased activity of superficial neck muscles during rest, deep breathing and during a CCFT compared to those who breathe with a costo-diaphragmatic breathing pattern (Santanter et al., 2000; Falla et al., 2004; Jull et al., 2004; Cagnie et al., 2008; Koh and Jung, 2013; Valenzuela et al., 2017). Surface electromyography (sEMG) of the sternocleidomastoid and anterior scalene during quiet and deep breathing has not been previously investigated in relation to other measures of neck dysfunction and breathing outcomes.

Lastly, psychological factors such as anxiety and depression have been reported to be associated with neck pain and disability (Demyttenaere et al., 2007; Blozik et al., 2009; López-de-Uralde-Villanueva et al., 2018) as well as dysfunctional breathing (Gardner, 1996; Hegel and Fergusson, 1997; Jack et al., 2003; Jack et al., 2004; Meuret and Ritz, 2010; Agahe et al 2012; Boulding et al., 2016; Esser et al., 2017). The relationship of perceived stress with measures of neck pain and how this relates to breathing, is unknown.

1.3 Research question

Is there a relationship between neck pain and breathing outcomes; and is this relationship related to muscle activity of the sternocleidomastoid and scalene muscles during breathing or to perceived stress?

1.4 Aim

The aim of the study is to investigate the relationship between neck pain and breathing, and how this is related to muscle activity of the sternocleidomastoid and scalene muscles during breathing, and perceived stress.

1.5 Objectives

The objectives of the study are to determine:

1. Deep neck flexor strength (CCFT) in participants with neck pain compared to matched controls.
2. Measures of breathing (respiratory rate, CTMT, breathing pattern, NQ, SEBQ, BHT) in participants with neck pain compared to matched controls.
3. Muscle activity (sEMG) of the sternocleidomastoid and scalene muscles during quiet and deep breathing in participants with neck pain compared to matched controls.
4. Perceived stress in participants with neck pain compared to matched controls.
5. The association of neck pain (NRS), neck disability (NDI) and deep neck flexor strength (CCFT) with measures of breathing.
6. The association of sternocleidomastoid and scalene muscle activity during quiet and deep breathing with neck pain (NRS) and neck disability (NDI).

7. The association of sternocleidomastoid and scalene muscle activity during quiet and deep breathing with thoracic expansion.
8. The difference in sternocleidomastoid and scalene muscle activity during quiet and deep breathing between upper-costal and costo-diaphragmatic breathing patterns.
9. The association of perceived stress with neck pain and disability as well as with measures of breathing.

1.6 Significance

A relationship between neck pain and breathing has already been established in the literature. However, many of these studies used one or two breathing outcomes, and therefore it is unclear which components of breathing are most affected in people with neck pain. By using multiple breathing assessment tools that evaluate various aspects of breathing, we can gain better understanding into which breathing components are most associated with neck pain. This will help to guide assessment and treatment approaches.

Some of the assessment methods used in previous literature, such as spirometry, respiratory strength measuring and capnography, are not easily accessible to the average health professional. Multiple easy-to-use and accessible assessments of breathing were used in this study and analysed alongside neck-related assessment tools. By doing this, the researcher hoped to highlight accessible breathing assessments that are relevant and beneficial in patients with neck pain.

Investigating the muscle activity of scalene and sternocleidomastoid muscles during breathing in relation to other breathing and neck-related outcomes provides insight into the neuromuscular dysfunction associated with neck pain and how this relates to breathing.

Psychological factors are significant in the development and prognosis of neck pain and may influence breathing pattern irregularities. Investigating perceived stress in relation to breathing and neck-related assessments, provides insight into how stress influences breathing and neck dysfunction.

If health professionals have a better understanding of possible factors that are contributing towards the development and recurrence of neck pain and can assess these factors in their rooms, they will be better equipped to treat neck pain, lessening the burden of neck pain on society.

1.7 Organisation of the dissertation

Chapter 1

Introduction and scope of the dissertation

- Background
- Problem statement
- Research question
- Aims and objectives
- Significance of the research

Chapter 2

Literature review including:

- Introduction
- Neck pain epidemiology
- Anatomy of the neck
- Anatomy of the thorax
- Biomechanics and neural control of breathing
- Dysfunctional breathing
- The relationship between neck pain and breathing from a biomechanical, biochemical and psychological perspective
- Assessment methods for neck pain and dysfunction, breathing, muscle activity and psychological factors
- Conclusion

Chapter 3

Methodology of the dissertation including:

- Study design and study setting
- Participants: sample population source, size and selection with inclusion and exclusion criteria
- Instrumentation and outcome measures with explanations
- Procedure: explanation of procedure during the pilot and main study
- Ethical considerations
- Data analysis: describing which statistical tests were used

Chapter 4

- Results of the research study following statistical analysis

Chapter 5

- Discussion: presenting the main findings of the research in relation to other literature

Chapter 6

- Conclusions
- Strengths of this study
- Limitations of this study
- Clinical recommendations and Recommendations for future studies

Figure 1-1 Organisation of the dissertation

2 LITERATURE REVIEW

2.1 Introduction

Neck pain is common in the general population with high rates of chronicity and recurrence (Hogg-Johnson et al., 2008; Blanpied et al., 2017) and a generally poor prognosis (Hush et al., 2011). The neck is connected to the thorax anatomically with many fascial and muscle connections (Drake et al., 2010). This may be relevant clinically because neck pain is associated with a change in breathing pattern and hypocapnia as well as a reduction in respiratory function, respiratory strength and thoracic expansion (Perri and Halford, 2004; Kapreli et al., 2009; Dimitriadis et al., 2014; Wirth et al., 2014; Halim et al., 2016; Kahlaee et al., 2017; López-de-Uralde-Villanueva et al., 2018). A change in breathing pattern that compromises its function in the absence of other pathology is termed dysfunctional breathing (Courtney, 2016; Barker et al., 2018). Dysfunctional breathing has three components: biomechanical, biochemical and psychological (Chaitow et al., 2014b; Courtney, 2016). This literature review will evaluate the way in which these three components of breathing relate to neck pain. The evidence regarding validity and reliability of outcome measures used in this study to assess neck pain and dysfunction as well as breathing, will be reviewed. The following keywords were used in the literature search: neck pain, breathing, hyperventilation, dysfunctional breathing, breathing pattern disorders, electromyography, muscle activity, Cranio-Cervical Flexion Test. The databases searched were as follows: EBSCOhost, Pubmed, Journal Storage. Literature published since inception up until 16 January 2020 have been included in this literature review.

2.2 Neck pain epidemiology

Neck pain is a common condition (Hogg-Johnson et al., 2008; Blanpied et al., 2017). The 12 month prevalence of the general global population in adults between 1980 and 2006 was 30% to 50% (Hogg-Johnson et al., 2008) and lifetime prevalence has been reported to be between 22% and 70% (Blanpied et al., 2017). The global prevalence of neck pain lasting more than three months and the global burden of neck pain has been steadily increasing from 1990 to 2015 (Hurwitz et al., 2018b). There is limited evidence regarding the prevalence and economic burden of neck pain for adults in the South African context (Basson et al., 2019). The prevalence of neck pain in South African high-school students is reported to be between 20% and 54% (Smith et al., 2008; Mafanya and Rhoda, 2011). Neck pain has a high economic burden due to health costs and time away from work (Hoy et al., 2010; Blanpied et al., 2017).

Neck pain and low back pain were rated as the leading cause for disability globally in 2015 (Vos et al., 2016; Hurwitz et al., 2018a) and neck pain itself is consistently rated in the top five causes of disability (Vos et al., 2012; Hoy et al., 2014; Vos et al., 2016). Disability caused by neck pain and low back pain is greater for people from a higher socio-demographic index (Vos et al., 2016) and was reported to increase by more than 17% between 1990 and 2015 (Kassebaum et al., 2016). Pain and disability related to idiopathic neck pain are strongly related to cognitive factors such as catastrophising and low pain vigilance or awareness (Thompson et al., 2010).

Psychosocial factors including feeling depressed and perceiving conflict, with associated emotion-related muscle tension, are the strongest risk factors for developing first episode neck pain (Kim et al., 2018). Other strong risk factors for the occurrence of neck pain include being female and having had previous neck pain (Blanpied et al., 2017). However, it was reported that being female, middle-aged and having a history of smoking have a lower degree of risk compared to psychosocial factors (Kim et al., 2018). Risk factors of lower strength include high body mass index (BMI), a history of low back pain, increased computer usage, sedentary work, manual labour, long distance driving, high job demands, low social or work support, decreased control over work time and uncertainty regarding employment (Skov et al., 1996; Hoy et al., 2014; Cohen, 2015; Blanpied et al., 2017). Neck pain is associated with poor education, infrequent physical activity, anxiety, depression, and low social support (Blozik et al., 2009). In low- and middle-income countries, neck pain is associated with being female and increased age (Hurwitz et al., 2018a). There is very little evidence that physical factors increase the risk of developing neck pain and, in fact, most of the risk factors for neck pain are modifiable and can therefore be addressed (Kim et al., 2018).

General prognosis of neck pain is poor (Hush et al., 2011; Walton et al., 2013). Less than 50% of people who experience neck pain will have full resolution of pain and disability in six weeks, and many people continue to have persistent pain, of a higher intensity than that of persistent low back pain (Hush et al., 2011). This is likely to affect daily function and quality of life (Hush et al., 2011). Chronicity and recurrence of neck pain is high (Carroll et al., 2008; Blanpied et al., 2017) with between 50% and 85% of people with neck pain reporting recurrent episodes one to five years later (Carroll et al., 2008). Coté et al. (2004) found in an analysis of 1,100 Canadian participants, less than 40% of those with neck pain reported resolution of their symptoms one year later. Poor prognosis is associated with age (middle-aged or older), being female, having had a history of previous neck pain, co-existing low back pain or associated upper-limb symptoms, cycling as a regular activity, low self-rated general health and low self-rated quality of life, poor psychological health and poor social support (Croft et al., 2001; Coté et al., 2004; Carroll et al., 2008; Hogg-Johnson et al., 2008; Hoy et al., 2010; Cohen, 2015). In a review of prognostic factors for neck pain, the strongest evidence for poor prognosis was found to be old age and a history of musculoskeletal disorders prior to the onset of neck pain (Walton et al., 2013).

Regular physical activity may also provide a favourable prognosis (Walton et al., 2013). In the longitudinal study done by Carroll et al. (2008), it was found that the strongest predictor for a good prognosis was being positive, self-confident and less reliant on social company, and a worse prognosis was associated with negative psychosocial factors. Psychological and social factors were also reported to be important in determining prognosis of neck pain by Karels et al. (2007) over a six-month period. There is no evidence to support that disc or joint degeneration, employment status or exercise level influences the prognosis of neck pain (Carroll et al., 2008; Hogg-Johnson et al., 2008).

In conclusion, neck pain is common and has a high rate of recurrence and chronicity. Psychosocial factors, previous neck pain and female sex are the strongest risk factors for the development of neck pain and play an important role in determining the prognosis of neck pain. The next section will discuss the anatomy of the neck and thorax as well as the biomechanics of breathing and how this relates to the neck.

2.3 Anatomy and biomechanics

2.3.1 Relevant anatomy of the neck

The neck forms a tube connecting the head with the thorax. Superiorly, it is bordered by the mandible anteriorly, and occipital bone posteriorly (Drake et al., 2010). Inferiorly, it is bordered by the manubrium anteriorly, and intervertebral disc of C7 posteriorly (Drake et al., 2010). There are multiple layers of fascia in the neck (Drake et al., 2010). The superficial fascia contains the platysma muscle within it and connects the thorax with the neck and face (Drake et al., 2010). The deeper layer surrounds most of the neck structures, including the sternocleidomastoid, and the deepest layers envelop the four compartments of the neck (Drake et al., 2010). The four compartments of the neck include: the visceral compartment anteriorly (which contains the digestive and respiratory systems, as well as endocrine glands); a vertebral compartment posteriorly (containing the vertebrae, spinal cord, cervical nerves and deep cervical muscles, including the scalene muscles); and two vascular compartments on either lateral side of the neck (containing major blood vessels and the vagus nerve) (Drake et al., 2010).

The neck can be further divided into two main triangles: the anterior and posterior triangles. The anterior triangle is formed by the mandible superiorly, the sternocleidomastoid posteriorly and the midline of the neck anteriorly (Drake et al., 2010). The posterior triangle is formed by the clavicle inferiorly, the upper trapezius posteriorly, and the sternocleidomastoid anteriorly (Drake et al., 2010). The anterior triangle contains many structures passing from the head and neck to the thorax; and the posterior triangle contains structures passing from the neck through to the upper limbs (Drake et al., 2010). The muscles in the neck assist with neck posture, movement of the neck and shoulder, as well as thoracic expansion (Drake et al., 2010). Two of the most researched muscles in the neck that are involved in respiration and thoracic expansion are the scalene and sternocleidomastoid muscles (Pryor and Prasad, 2008).

The scalene muscles are three muscles situated lateral to the cervical spine and deep to the sternocleidomastoid (Drake et al., 2010). The anterior scalene originates from the anterior transverse process of C3 to C6, inserts into the first rib and is innervated by the anterior rami of C4 to C7 (Drake et al., 2010). The middle scalene muscle originates from the transverse processes of C2 to C7, inserts into the first rib and is innervated by anterior rami of C3 to C7 (Drake et al., 2010). The posterior scalene muscle originates from the transverse processes C4 to C6, inserts into the second rib and is innervated by the anterior rami of C5 to C7 (Drake et al., 2010). The scalene muscles side-flex the neck, elevate the first two ribs and help to stabilise the neck and upper ribcage (de Troyer et al., 2005; Drake et al., 2010).

The sternocleidomastoid forms the margins of the anterior and posterior triangle of the neck and consists of two heads (Drake et al., 2010). The sternal head originates from the anterio-superior manubrium of the sternum and the clavicular head originates from the medio-superior third of the clavicle (Drake et al., 2010). The sternocleidomastoid connects to form one muscle bulk inserting into the lateral superior nuchal line and mastoid process of the temporal bone (Drake et al., 2010). When the sternocleidomastoid contracts unilaterally, the head tilts toward the same side and rotates toward the opposite side (Drake et al., 2010). When there is bilateral activation, the head is pulled into flexion (Drake et al., 2010). The sternocleidomastoid is also an accessory breathing muscle, lifting the sternum and contributing towards upper thoracic expansion during increased respiratory demand (Kourouris and Dimititroulis, 2001; Drake et al., 2010; Sieck et al., 2013). Nerve supply of the sternocleidomastoid is the accessory nerve (cranial nerve XI) and branches of the cervical spinal nerves (anterior rami of C2 and C3) (Drake et al., 2010).

2.3.2 Relevant anatomy of the thorax

The thorax forms an irregular cylinder which is closed inferiorly by the diaphragm and open superiorly to connect with the neck (Drake et al., 2010). The thoracic wall is made up of the ribs, sternum, vertebrae and muscles that surround or bridge these structures (Drake et al., 2010). Within the thoracic cavity lies the left and right pleural cavities which surround the left and right lungs; and the mediastinum which surrounds the heart, oesophagus, trachea, major nerves and major systemic blood vessels (Drake et al., 2010).

There are 12 ribs on either side of the thorax. Posteriorly the ribs attach to the thoracic vertebrae and their intervertebral discs, anteriorly the first ten connect via costal cartilages to the sternum, and the lower two ribs are floating ribs with no anterior connection (Drake et al., 2010). The ribs have limited movement posteriorly due to many ligaments holding them securely in place, but anteriorly the costal cartilaginous connection and the mobility of the sternum allows for increased movement of the anterior thoracic wall (Drake et al., 2010). The thorax provides attachment sites for many muscles of the back, abdomen, upper limb and neck, which, as well as their movement function, assist in stabilising and expanding the thorax (Drake et al., 2010). The largest muscle attaching to the thorax and the main muscle responsible for thoracic expansion is the diaphragm (Pryor and Prasad, 2008; Drake et al., 2010).

The diaphragm separates the thoracic cavity from the abdominal cavity and forms two thin musculotendinous domes that extend superiorly (Drake et al., 2010). It originates from the xiphoid process of the sternum, the costal margin of the lower ribs, ligaments of the posterior abdomen and the transverse processes of the lumbar vertebrae and inserts into a central tendon (Drake et al., 2010; Nason et al., 2012). The diaphragm is innervated by the phrenic nerve which originates from spinal nerves C3 to C5 (Drake et al., 2010; Nason et al., 2012). The main function of the diaphragm is to expand the thoracic cavity and contribute towards inspiration (Pryor and Prasad, 2008). However, during tasks that challenge trunk stability, the diaphragm is needed for postural control and is active throughout the breath cycle (Hodges and Gandevia, 2000; Kolar et al., 2010). To provide optimum expansion during inspiration, the diaphragm is required to work with other muscles including the intercostal muscles, scalene muscles as accessory muscles (Pryor and Prasad, 2008; de Troyer and Wilson, 2016). The anatomy of the scalene muscles and the sternocleidomastoid, an important neck accessory muscle, have been reviewed in section 2.3.1 and their contribution towards respiration will be covered in section 2.3.3.

The intercostal muscles are small muscles running obliquely to bridge the intercostal spaces between ribs and are innervated by the intercostal nerves (de Troyer et al., 2005; Drake et al., 2010). The most superficial layer is formed by the external intercostal muscles, under which lie the internal intercostal muscles, and the innermost intercostal muscles are the deepest layer (Drake et al., 2010).

Within the outer structure of the thorax lie pleural cavities which surround the lateral, superior and inferior lungs (Drake et al., 2010). The walls of the pleural cavities, the pleurae, are divided into two main sections: the parietal and visceral pleura (Drake et al., 2010). The visceral pleurae are firmly attached to each lung and form the medial wall of the pleural cavities (Drake et al., 2010). The parietal pleura can be further categorised depending on its location into the cervical pleura, mediastinal pleura, diaphragmatic pleura and costal pleura (Drake et al., 2010). Covering the superior cervical pleura is fascia called the suprapleural membrane (Drake et al., 2010). This membrane has attachments to the first rib, the transverse process of C7 vertebra, and the scalene muscles of the neck (Drake et al., 2010). This membrane assists in supporting the pleural cavity in the apical region (Drake et al., 2010). The mediastinal and diaphragmatic pleura are innervated by the phrenic nerve (Drake et al., 2010). Pain from structures innervated by the phrenic nerve may refer to dermatomal areas of C3, C4 and C5 (origins of the phrenic nerve) and present as neck or shoulder pain (Drake et al., 2010).

The main functions of the thorax are to protect vital organs, nerves and vessels, to provide a pathway for the oesophagus, vagus nerves and thoracic duct to pass from the neck to the abdominal region and house the organs and musculoskeletal structures necessary to breathe (Drake et al., 2010). The open superior thoracic aperture allows for structures to enter the thorax from the neck and creates a space for the superior pleural cavity to extend into the root of the neck above the first rib (Drake et al., 2010). The axillary inlets, situated on the lateral ends of the superior thoracic aperture, connect the neck with the upper limbs and contain the brachial plexuses as well as blood vessels passing down the arms (Drake et al., 2010).

Therefore, the thorax and neck are closely connected with many fascial and neuromuscular connections. Furthermore, many structures including respiratory organs, the oesophagus, nerves and blood vessels, pass through the neck to the thorax. The thorax provides surface area for the attachment of many muscles, including the diaphragm, sternocleidomastoid and scalene muscles, which contribute towards thoracic expansion and inspiration. The phrenic nerve, which originates from C3 to C5 and passes through the thorax to innervate the diaphragm and parts of the parietal pleura, may be a source of neck and shoulder pain. The biomechanics and neural control of breathing will be further discussed in the next section.

2.3.3 The biomechanics and neural control of breathing

The action of breathing results in the ribcage moving in vertical, lateral and anteroposterior directions (de Groote et al. 1997; Drake et al., 2010). The anterior attachments of the ribs are lower than the posterior attachments; therefore, elevation of the ribs attaching to the sternum causes the sternum to move forward and superior, increasing the anteroposterior dimension of the thorax, and elevation of the lower ribs increases the lateral dimensions of the thorax (Koulouris and Dimitroulis, 2001; de Troyer et al., 2005; Drake et al., 2010). The forward movement of the sternum is often referred to as a "pump handle" motion and the lateral movement is referred to as the "bucket handle" motion (Koulouris and Dimitroulis, 2001; Drake et al., 2010). In addition to anterior and lateral movement, there is also a vertical expansion of the thoracic cavity downwards due to flattening of the diaphragm (Drake et al., 2010). This action of thoracic expansion in multiple directions, as a result of various joints moving and muscles contracting, creates a change in intra-thoracic pressure which draws air into the lung so that breathing can take place (Richardson, 2006; Drake et al., 2010). The muscles responsible for thoracic expansion during inspiration include the diaphragm, intercostal muscles, scalene muscles and accessory muscles (Pryor and Prasad, 2008; Drake et al., 2010). The way in which these muscles contribute to the motion of breathing will be further explained.

The diaphragm is the main muscle responsible for the breathing action (Pryor and Prasad, 2008; Nason et al., 2012). When contracted, the diaphragm increases the vertical and lateral dimensions of the lower ribcage (Drake et al., 2010). Lateral thoracic expansion is dependent on the appositional force created by the diaphragm flattening and pushing down into the abdominal cavity (de Troyer and Wilson, 2016). The resistance provided by the abdominal pressure, helps to widen the diaphragm and results in the ribs being pushed outward to the sides (de Troyer and Wilson, 2016). When the diaphragm acts independently of the neck muscles and intercostal muscles, it provides expansion of the lower ribcage only and may result in an inward movement of the upper ribcage (de Troyer and Wilson, 2016). Therefore, although the diaphragm is the main breathing muscle, it is required to work with other muscles to achieve optimum thoracic expansion (Pryor and Prasad, 2008; de Troyer and Wilson, 2016).

The intercostal, subcostales and transversus thoracis muscles play a large role in stabilising and elevating the ribs during breathing (de Troyer et al., 2005; Drake et al., 2010). During quiet breathing it is mainly the parasternal intercostal muscles that participate in inspiration (Gransee et al., 2012; Sieck et al., 2013). The intercostal muscles activate in segments depending on the stage of breathing and, together with the subcostales and transversus thoracis muscles, elevate the ribs and provide postural support for the intercostal spaces (de Troyer et al., 2005; Drake et al., 2010).

To allow for rib elevation by the intercostal muscles, stabilisation of the upper ribcage is needed, which is provided by neck muscles, especially the scalene muscles (de Troyer et al., 2005). The scalene muscles also act to elevate the first two ribs, providing upper thoracic expansion (Drake et al., 2010). Electromyography studies show that the anterior scalene muscle activates along with the parasternal muscles and diaphragm in a phasic fashion during quiet breathing and therefore the scalene muscles are considered primary respiratory muscles (de Troyer and Estenne, 1984; Chiti et al., 2008; Pryor and Prasad, 2008).

Accessory respiratory muscles assist with thoracic expansion during increased respiratory demand (Pryor and Prasad, 2008; Drake et al., 2010). Accessory muscles of inspiration include the sternocleidomastoid, pectoralis minor, trapezius, serrati and erector spinae muscles, of which the sternocleidomastoid is the most important and well researched (Koulouris and Dimitroulis, 2001; Pryor and Prasad, 2008). The sternocleidomastoid assists in elevating the sternum and upper ribcage in a pump-handle motion (Koulouris and Dimitroulis, 2001; de Troyer et al., 2005). When the sternocleidomastoid contracts, it causes a decrease in intrathoracic pressure and this results in an increase in total lung capacity and vital capacity (VC) (Koulouris and Dimiroulis, 2001). The sternocleidomastoid is only recruited in healthy people at around 20% of the maximal inspiratory pressure (Chiti et al., 2008) and therefore is not active during quiet breathing. The scalene muscle has a mechanical advantage over the sternocleidomastoid; however, the effect of the muscle contraction is similar due to the increased bulk of the sternocleidomastoid muscle (Legrand et al., 2003).

The action of the respiration is controlled through complex cortical, brainstem and spinal adaption (Hill and Eastwood, 2011) influenced by changing mechanical, metabolic and emotional demands (Gransee et al., 2012; Mortola, 2019) and is linked with sympathetic and vagal activity (Eckberg, 2003). Importantly, this complicated subconscious control of respiration can also be overridden by conscious cortical control (Richardson, 2006).

Therefore, respiration is a biomechanical action caused by the contraction of many muscles that results in thoracic expansion drawing air into the lungs. The most important respiratory muscles have been discussed and include the diaphragm, intercostal muscles, scalene muscles and the sternocleidomastoid muscle. The action of respiration is controlled by a complex regulation that responds to mechanical, chemical, neural and cortical stimuli. Therefore, breathing pattern may change according to any one of these influences.

2.4 Dysfunctional breathing

Dysfunctional breathing, also referred to as breathing pattern disorders, occurs when there are changes in respiration that compromise the normal function of breathing and result in intermittent or chronic symptoms (Boulding et al., 2016; Courtney, 2016). The main function of breathing is gaseous exchange. However, breathing also influences blood pH level, emotional and mental wellbeing, speech and expression, bodily fluid circulation, digestion, motor control, posture and spinal stability (Chaitow et al., 2014a; Courtney, 2016). Hyperventilation is the most researched type of dysfunctional breathing (Gilbert, 2014a).

Reported signs and symptoms of dysfunctional breathing include dyspnoea, breath-holding, frequent deep sighing, difficulty taking a deep breath, irregular respiratory rhythm, mild hyperinflation, self-reported breathing restriction that does not respond fully to medication, dizziness, reduced concentration, visual disturbances, tachycardia, sweating, chest pain, coldness or paraesthesia in the peripheries, tetany, migraine-type headaches, upper-costal breathing and increased accessory muscle activation (Brodtkorb et al., 1990; Hagman et al., 2008; Courtney, 2009; Bradley, 2014; Barker and Everald, 2015; Boulding et al., 2016; Barker et al., 2018; Vidotto et al., 2019). Many of these symptoms, originally classified as hyperventilation symptoms, are now included in the broader diagnosis of dysfunctional breathing (Boulding et al., 2016). Hyperventilation-related hypocapnia has shown inconsistent correlations with symptom reporting, and it has therefore been suggested that the symptoms may also be a result of poor breathing mechanics and psychological factors (Gardener, 1996; Hornsveld and Garssen, 1997; Howel, 1997; Bradley, 2014; Boulding et al., 2016).

There are no clear diagnostic criteria for dysfunctional breathing, so the true prevalence and significance of this condition cannot be quantified (Barker et al., 2018; Vidotto et al., 2019). Using the NQ, which is the most commonly used assessment tool in the literature, dysfunctional breathing has a prevalence of 9.5% in the adult population (Thomas et al., 2005). Dysfunctional breathing is more common in females (Agahe et al., 2012; Veidal et al., 2017) and is associated with reduced quality of life and lower general health (Hagman et al., 2008; Chenivesse et al., 2014; Veidal et al., 2017; Ok et al., 2018). Dysfunctional breathing is often underdiagnosed or misdiagnosed as many of the symptoms are similar to those of respiratory, digestive or cardiac conditions (including asthma, irritable bowel syndrome and angina) (Hagman et al., 2008; Chaitow et al., 2014a; Barker et al., 2018; Vidotto et al., 2019). Dysfunctional breathing may also occur secondary to, and is associated with exaggerated symptoms of, conditions such gastro-oesophageal reflux, rhinitis and asthma (Agahe et al., 2012; Veidal et al., 2017; Barker et al., 2018).

Due to the complexity of the condition, diagnosis of dysfunctional breathing should be made following a multidimensional assessment that includes subjective and objective tests after the exclusion of other pathology, or once other pathology (such as asthma) is controlled (Bradley, 2014; van Dixhoorn and Folgering, 2015; Boulding et al., 2016; Vidotto et al., 2019). There are three dimensions that should be considered when assessing and treating dysfunctional breathing: biomechanical, biochemical and psychological (Gardener, 1996; Chaitow et al., 2014b; Courtney, 2016). These three dimensions of breathing will be further discussed with regard to how they contribute towards the relationship between neck pain and breathing.

2.5 The relationship between neck pain and breathing from a biomechanical, biochemical and psychological perspective

2.5.1 Biomechanical

The biomechanical aspect of breathing refers to the way in which the ribcage and muscles influence patterns of breathing (Courtney, 2016). This section will discuss how lung function, breathing patterns, muscle dysfunction and posture influence the relationship between neck pain and breathing.

Lung function is determined by a combination of mechanical factors including properties of the lung and breathing airways as well as the strength of the respiratory muscles (Pryor and Prasad, 2008). It has been reported that people with neck pain have reduced lung function including VC, expiratory reserve volume (ERV), forced vital capacity (FVC) and maximum voluntary ventilation (MVV) (Kapreli et al., 2009; Dimitriadis et al., 2014; Wirth et al., 2014; Moawd and Ali, 2015; López-de-Uralde-Villanueva et al., 2018). Pain intensity and neck strength have been reported to be associated with MVV, VC and peak expiratory flow (PEF), with neck extensor strength being a predictor of MVV, VC and PEF (Dimitriadis et al., 2014). Forced expiratory volume in one second (FEV_1) and PEF are significantly reduced in participants with neck pain in some studies (Kapreli et al., 2009; López-de-Uralde-Villanueva et al., 2018) but not in others (Dimitriadis et al., 2014). Most of these studies assessed participants who had a history of chronic neck pain (duration of at least three months of intermittent neck pain). Although there is evidence that people with neck pain are likely to have reduced respiratory function, Wirth et al. (2014) found that these differences were not significant, perhaps due to the mild pain reported by the participants in their study. Dimitriadis et al. (2016) reports that the most significant lung function parameter in association with neck pain is MVV. They suggest this is because MVV reflects general respiratory function including airway resistance, lung and chest wall compliance, respiratory control mechanisms and respiratory muscle function, as well as restrictive neuromuscular dysfunction.

Breathing pattern, often referred to as breathing type, is determined primarily by the breathing movement during inspiration. When upper thoracic movement exceeds lower thoracic movement, this is termed upper-costal breathing and when lower thoracic movement exceeds upper thoracic movement, this is termed costo-diaphragmatic breathing (Celhay et al., 2015). People experiencing neck pain are more likely to breathe using an upper-costal breathing pattern than healthy controls (Halim et al., 2016). In a pilot study "faulty breathing" (diagnosed by signs of chest dominant breathing, lack of lateral thoracic expansion and lifting of the clavicles) was more strongly associated with neck pain than with any other types of musculoskeletal dysfunction, including low back pain, headaches and thoracic pain (Perri and Halford, 2004). Upper-costal breathing, which is often characterised by increased elevation of the sternum and reduced lower thoracic expansion, is likely to result in overuse of the parasternal and accessory muscles and may put strain on the neck (Hruska, 1997; Courtney, 2009).

Participants with upper-costal breathing pattern demonstrate earlier recruitment and increased activation of the sternocleidomastoid muscle during the lower three levels of the CCFT compared to participants with a costo-diaphragmatic pattern (Cagnie et al., 2008). When the CCFT was performed during expiration, however, the sternocleidomastoid muscle activity was not significantly different between breathing pattern groups, confirming the use of accessory muscles during inspiration with an upper-costal breathing pattern (Cagnie et al., 2008). Electromyography studies report increased muscle activity of sternocleidomastoid and scalene muscles during deep breathing (Koh and Jung, 2013) and increased sternocleidomastoid activity during normal breathing, swallowing and clenching (Valenzuela et al., 2017) in those who breathe with upper-costal breathing compared to those with a costo-diaphragmatic pattern. In other literature, however, breathing type did not influence muscle activity of the sternocleidomastoid with clenching, chewing and swallowing (de Mayo et al., 2005; Gutiérrez et al., 2014), or with quiet or deep breathing (Celhay et al., 2015; Miralles et al., 2016).

An upper-costal breathing pattern may be the result of an ineffective, weak or dysfunctional diaphragm which fails to laterally expand the lower thorax and therefore results in an anterior and cranial compensation of the upper thorax (Hruska, 1997; Courtney, 2009; Chaitow et al., 2014b). This is supported by Halim et al. (2016), who reported that participants with neck pain are more likely to have reduced lower thoracic expansion which is correlated with an upper-costal breathing pattern. Magnetic resonance imaging has shown that the diaphragm sits higher in the thorax during upper-costal breathing and there are more cranial excursions at the anterior insertion compared to during costo-diaphragmatic breathing (Rychnovský and Pivec, 2009). The diaphragmatic muscle activity is also increased in people who breathe with an upper-costal breathing pattern, indicating diaphragmatic dysfunction (Celhay et al., 2015; Miralles et al., 2016). Reduced effectiveness of the diaphragm may also be caused by muscle shortening as a result of hyperventilation-associated hyperinflation (Hruska, 1997; Clifton-Smith, 2014). Symptoms of a weak, dysfunctional or ineffective diaphragm are more likely to be observed with increased respiratory demand or breathing difficulty (Hodges et al., 2001; Courtney, 2009; Depiazzi and Everard, 2016).

The diaphragm has two main functions: thoracic expansion during inspiration and postural stability (Hodges et al., 2001; Clifton-Smith, 2014; Kolar et al., 2014), both of which are challenged during exercise. The diaphragm depends on the abdominal muscles to create optimum intra-abdominal pressure to stabilise the spine (Clifton-Smith, 2014), and relies on this increase in pressure to produce lateral expansion (Hruska, 1997; Rychnovský and Pivec, 2009). Therefore, low tone or weakness in the abdominal muscles may limit the effectiveness of the diaphragm as a respiratory muscle and key spinal and postural stabiliser. Weakness in the abdominal muscles is associated with reduced ERV and VC (Koulouris and Dimiroulis, 2001), demonstrating its effect on respiration. The muscles in the neck, along with contributing towards respiration and neck movement, also assist with postural stability. Increased postural sway is observed following neck extensor fatigue (Stapley et al., 2006), and is evident in participants with neck pain (Juul-Kristensen et al., 2013). Due to the overlap of muscles used in respiration and postural stability, weakness in the respiratory muscles may result in reduced postural and spinal stability or vice versa.

The relationship between neck and respiratory strength is supported by reports of reduced respiratory strength (maximum inspiratory and expiratory pressures) in people with neck pain compared to those without neck pain (Dimitriadis et al., 2013a; Moawd and Ali, 2015). Furthermore, respiratory strength is positively correlated with neck strength, including deep neck flexor strength, for those with and without neck pain (Dimitriadis et al., 2013a; López-de-Uralde-Villanueva et al., 2018). Respiratory strength can be predicted by neck flexor strength (measured using a hand-held dynamometer) (López-de-Uralde-Villanueva et al., 2018) and neck extensor strength (Dimitriadis et al., 2013a). Respiratory strength measures are also significantly correlated to neck disability scores (Dimitriadis et al., 2013a; Wirth et al., 2014). López-de-Uralde-Villanueva et al. (2018) reports that respiratory strength and neck strength were only reduced in those with moderate to severe neck disability on the NDI.

Strengthening the respiratory muscles with resisted inspiratory exercises not only improves inspiratory strength but also neck flexor endurance strength and reduces neck pain (Wirth et al., 2016). The scalene and sternocleidomastoid muscles may be more vulnerable to fatigue than the diaphragm and have been reported to show earlier decrease in muscle activity following an inspiratory load (Da Gama et al., 2013). Muscle fatigue can lead to muscle spasm and trigger point formation causing pain (Mense, 2008).

People with neck pain are likely to have reduced deep neck flexor strength (Chiu et al., 2005; Jull et al., 2008), and this is especially evident for those with moderate disability as identified by the NDI (O'Leary et al., 2007). During a CCFT, people with neck pain demonstrate lower muscle activity of the deep neck flexor muscles and this corresponds to higher activity of the sternocleidomastoid and anterior scalene muscles (Falla et al., 2004; Jull et al., 2004). This dysfunction may be related to pain, as deep neck flexor muscle activity decreased and the sternocleidomastoid activity subsequently increased to perform the CCFT, after pain was induced with a saline injection into healthy volunteers' trapezius muscle (Cagnie et al., 2011).

O'Leary et al. (2011) reported that an increase in sternocleidomastoid and anterior scalene muscle activity during the CCFT was positively correlated with pain scores but not to disability measured on the NDI. This muscle dysfunction is also demonstrated in other tasks. People experiencing cervical-mandibular pain exhibit increased activity of the sternocleidomastoid at rest, with swallowing and clenching, compared to people without pain (Santanter et al., 2000) and people with chronic neck pain demonstrate increased activation duration of sternocleidomastoid during a functional upper limb task (Tsang et al., 2014). During a balance task, the anterior scalene, sternocleidomastoid, upper trapezius and neck extensors of people with neck pain are increased compared to those without neck pain (Juul-Kristensen et al., 2013). This demonstrates that the muscles of the neck used in inspiration, such as the sternocleidomastoid and anterior scalene muscles, show increased activity in people with neck pain during various tasks including upper limb activities, jaw movements, postural activities, and during rest.

Muscle activity of the neck muscles may also be influenced by head posture. In participants with a forward head posture, electromyography (EMG) readings of sternocleidomastoid and pectoralis major, as well as upper trapezius in women, were less during deep breathing in people with a head forward posture than those with neutral posture (Han et al., 2016). However, another study reported a positive correlation between forward head posture in healthy volunteers and EMG ratios of sternocleidomastoid and upper trapezius during combined quiet and deep breathing, indicating increased muscle activity with a forward head posture (Kim et al., 2017). Head posture was reported not to influence sternocleidomastoid activity during normal breathing, swallowing and clenching in participants with cervico-mandibular pain (Santanter et al., 2000), or during a CCFT in participants without neck pain (Cagnie et al., 2008).

A forward head posture is common in people with neck pain and may be associated with neck weakness (Yip et al., 2008; Silva et al., 2009; Nejati et al., 2014). A forward head posture and associated weak cervical stabilisers may disturb normal breathing movement as the respiratory muscles rely on a stable spine during thoracic expansion (Kapreli et al., 2008). A forward head posture is associated with respiratory weakness (Kapreli et al., 2009; Halim et al., 2016; Zafar et al., 2018) and reduced respiratory function (Han et al., 2016) as well as a reduction in lower thoracic expansion (Halim et al., 2016). However, no relationship has been found between head posture and breathing pattern (Cagnie et al., 2008; Halim et al., 2016). A forward head posture may be a compensatory action for breathing difficulty or a weak diaphragm, as having the head in front of the body increases the resting length of the diaphragm (Hruska, 1997; Pryor and Prasad, 2008; Courtney, 2009).

In conclusion, people with neck pain are more likely to have reduced respiratory function, reduced respiratory strength and an upper-costal breathing pattern. An upper-costal breathing pattern may be due to a weak diaphragm. The diaphragm, abdominal muscles and neck muscles contribute towards respiration and spinal stability. Thus, weakness in any of these muscles may have a negative effect on spinal stability as well as respiratory strength and function. People with neck pain are also more likely to have increased muscle activity of the neck muscles with various tasks including breathing at rest. A head forward posture influences the neck muscle activation during breathing and diaphragm positioning but not the breathing pattern. Therefore, the neck is related to breathing function, patterns, strength, muscle activation and posture. The biomechanical motion of breathing is controlled and influenced by many inputs, including chemical input through CO_2 levels. The way in which the neck may be related to breathing from a physiological and biochemical perspective will be discussed in the next section.

2.5.2 Biochemical

The main function of breathing is for gaseous exchange and this not only ensures adequate oxygen but also correct pH levels for physiological processes to occur (Siggaard-Andersen, 2005; Bradley, 2014). The acid-base balance is mediated by the presence of hydrogen ions and this is influenced by the level of CO_2 (Siggaard-

Andersen, 2005). The CO_2 level has a direct influence on cerebral blood flow, making the body more sensitive to CO_2 than it is to oxygen (Richardson, 2006; Gilbert, 2014a; Willie et al., 2014). When the body senses a rise in CO_2, the respiratory rate and depth increases to restore normal levels (Richardson, 2006). The respiratory response to a rise or drop in CO_2 is faster and more efficient than the metabolic compensation which is often unable to completely correct the CO_2 level (Siggaard-Andersen, 2005). In chronic states of compensation, the body is unable to maintain optimal homeostatic pH levels and a new threshold of CO_2 may be set (Gilbert, 2014a). In this section we will discuss the body's response to hypercapnia and hypocapnia focusing on the effects of hyperventilation and the way in which this relates to neck pain.

Hypercapnia results in an upper-costal breathing pattern, increased diaphragmatic muscle contraction velocity, reduced diaphragmatic force production, and increased abdominal muscle activation during expiration (Romagnoli et al., 2004). The diaphragm and transverse abdominus cease to adapt effectively to postural load during hypercapnia, putting the spine at risk for injury (Hodges et al., 2001). There are no studies looking at the effect of hypercapnia on the functioning of the neck muscles. However, as discussed in the previous section, an upper-costal breathing pattern may put strain on the neck muscles. Furthermore, the diaphragm, abdominal muscles and neck muscles all contribute towards postural stability, and if hypercapnia affects muscle functioning of the diaphragm and transverse abdominus, it is likely to also cause muscle dysfunction in the neck region as well. Therefore, hypercapnia may result in biomechanical breathing pattern changes and muscle dysfunction that influences neck pain.

Hypocapnia is a common and well researched problem in association with hyperventilation (Bradley, 2014), and is common in people with chronic neck pain (McLaughlin et al., 2010; Dimitriadis et al., 2013b). Hyperventilation is a type of dysfunctional breathing defined as excess breathing beyond the body's required metabolic requirements that results in acute or chronic symptoms (Gardner, 1996; Pryor and Prasad, 2008; Bradley, 2014). Hypocapnia during hyperventilation results in reduced blood flow to various areas of the brain, with grey matter being affected the most (Terekhin and Forster, 2006; Willie et al., 2014). This is confirmed by magnetic resonance imaging reports that show a reduction in cross sectional area of the middle cerebral artery by around eight percent during hyperventilation-related hypocapnia (Coverdale et al., 2014). This reduction in cerebral blood flow reduces cognitive performance (Van Diest et al., 2000) and influences the processing of nociceptive and motor inputs (Terekhin and Forster, 2006). Hyperventilation influences activation of muscles and results in neuromuscular dysfunction, which is related to hypocapnia and independent of the reduction in cerebral blood flow (Hartley et al., 2016).

Hypocapnia causes a respiratory alkalosis which has been reported to result in an increase in muscle tension, muscle spasm, muscle ischemia and musculoskeletal pain (Schleifer et al., 2002). This muscle spasm and associated muscle ischemia may be a compensatory reaction in response to an alkalosis, as muscle ischemia leads to a release of substances that reduce the body's pH (Mense, 2008). As the body is constantly trying to maintain the correct pH for metabolic processes to occur, metabolic compensation may also contribute in restoring CO_2 levels and thus pH levels, especially in people who chronically hyperventilate (Gardener, 1996; Wilhelm et al., 2001). The process of metabolic compensation however, results in a loss of calcium in the urine which negatively affects muscle and nerve functioning, possibly contributing towards muscle pain and dysfunction (Gilbert, 2014a). The response of the body in restoring homeostatic levels may be effective for a short duration but if the biochemical imbalance and respiratory response continues, this will ultimately lead to adverse long-term emotional, physical and immunological results (Sikter et al., 2009; Chaitow et al., 2014a; Gilbert, 2014a; Barker and Everard, 2015; Carter and Goldstein, 2015; Hernando et al., 2016; Vidotto et al., 2019).

Hyperventilation may also occur as a coping mechanism to pain (Wilhelm et al., 2001). This is supported by decreased pain perception to a painful stimulus following hyperventilation and hypocapnia (Terekhin and Forster, 2006). Acute pain causes an increase in respiratory rate and people with chronic pain often have reduced arterial CO_2 levels (Wilhelm et al., 2001). In a sample of 29 participants with chronic neck pain or low back pain, all presented with hypocapnia (end tidal CO_2 less than 35 mmHg) (McLaughlin et al., 2010). In another study, participants with chronic neck pain had reduced CO_2 levels (determined by transcutaneous blood gas monitoring) with 42% of the participants with chronic neck pain diagnosed with hypocapnia (CO_2 less than 35 mmHg) (Dimitriadis et al., 2013b). Carbon dioxide levels have been reported to correlate with neck pain intensity, kinesiophobia, catastrophising tendencies and neck strength including that of deep neck flexors (Dimitriadis et al., 2013b). It has been suggested that hypocapnia may be a reason for work-stress related musculoskeletal pain including neck and shoulder pain (Schleifer et al., 2002).

Relaxed deep breathing and breath-holding reduces pain intensity to an acute painful stimulus (Zautra et al., 2010; Busch et al., 2012; Reyes del Paso et al., 2015). Breathing retraining with the focus of restoring normal CO_2 levels decreases reported pain and disability in participants with chronic pain (McLaughlin et al., 2010). It has been suggested that the mechanism of pain relief through deep breathing and breath-holding is due to the action of the diaphragm which facilitates venous and lymphatic flow, increasing the pressure in the vessels and stimulating baroreceptors (Reyes del Paso et al., 2015; Bordoni et al., 2016;). This activation of baroreceptors has an anti-nociceptive effect and reduces pain perception (Reyes del Paso et al., 2015; Bordoni et al., 2016). Diaphragmatic activation and resultant activation of baroreceptors also reduces sympathetic nervous system activity which is thought to be through the indirect connections of the phrenic nerve with the solitary nucleus (Bordoni et al., 2016). This may explain why the sympathetic response associated with hyperventilation and reduced cerebral blood flow (Willie et al., 2014), often results in an upper-costal breathing pattern and less diaphragmatic movement (Gilbert, 2014b).

In conclusion, hypercapnia is associated with an upper-costal breathing pattern and muscle dysfunction, especially of the spinal stabilisers. This is likely to put strain on the neck muscles and compromise the stability of the spine. Hypocapnia may be caused by hyperventilation and is likely to result in reduced cerebral blood flow, muscle spasm, and a loss of calcium through metabolic compensation. These factors may contribute to muscle and nerve dysfunction, increasing the risk of neck pain. Abnormal blood chemistry may not only cause pain but may be the result of pain-induced hyperventilation. Both hypercapnia and hypocapnia are associated with increased levels of anxiety (Van den Bergh et al., 2013). Hyperventilation is associated with the sympathetic response which is also related to psychological influences (Hernando et al., 2016). The role of psychological influences on breathing will be discussed in the next section.

2.5.3 Psychological

Anxiety and depression disorders are associated with increased levels of neck pain and especially related to chronic neck pain (Demyttenaere et al., 2007; Blozik et al., 2009; Dimitriadis et al., 2015; López-de-Uralde-Villanueva et al., 2018). Psychosocial factors do not only affect chronic neck pain but also play a role in the onset of pain at an acute level as well as the development of chronic pain and disability (Linton, 2000). Psychosocial factors have been shown to be the strongest risk factor for new onset of neck pain (Kim et al., 2018) and an important factor in the prognosis of neck pain (Karels et al., 2007). There is a strong association between pain and disability caused by idiopathic neck pain and catastrophising, reduced pain vigilance and poor pain awareness (Thompson et al., 2010). There is also a significant correlation between neck pain intensity and anxiety, as well as a correlation between neck disability and anxiety, depression and catastrophising (Dimitriadis et al., 2015). In this section we will discuss the body's response to stress and anxiety, and how this affects both breathing and musculoskeletal pain.

Stress is the body's response to physical or emotional threat and is mediated through the autonomic nervous system (Carter and Goldstein, 2015; Hernando et al., 2016). Physical threat indicates a disruption in physiological homeostasis, whereas emotional threat is the body's emotional response to actual or perceived danger in the external environment (Dampney, 2015). A disruption in physiological homeostasis has been discussed in relation to hypercapnia and hypocapnia in the biochemical section (section 2.5.2). Other causes of physical threat could be due to infection or injury (Dampney, 2015). For the purpose of this study, the role of emotional and cognitive stress in respiration and musculoskeletal pain will be further reviewed.

The autonomic nervous system is made up of the sympathetic and parasympathetic nervous systems, which assist in regulating cardiovascular and respiratory variables and the interaction between these variables (Widjaja et al., 2013; Hernando et al., 2016). Sympathetic activity is dominant during emotional and mental stress (Hernando et al., 2016). The sympathetic response prepares the body for action and increased metabolic requirements (Widjaja et al., 2013; Gilbert, 2014a; Grassmann et al., 2016). This associated cardiorespiratory response includes increased heart rate, respiratory rate and minute volume, increased sigh-frequency, irregular respiratory volume and rate, and reduced CO_2 levels (Grassmann et al., 2016; Hernando et al., 2016). In one study, higher respiratory rates were recorded in response to unpleasant images (Chenivesse et al., 2014). Increased respiratory rates and reduced CO_2 levels correlated with task difficulty during a cognitive exercise that induced mental stress, implying temporary hyperventilation (Grassmann et al., 2016).

Hyperventilation and a reduction of CO_2 levels are frequently reported in, and are associated with, anxiety disorders including generalised anxiety disorder and panic disorder (Jack et al., 2003; Jack et al., 2004; Meuret and Ritz, 2010; Agahe et al 2012; Van den Bergh et al., 2013; Boulding et al., 2016; Esser et al., 2017). People with panic disorder, and to a lesser extent generalised anxiety disorder, present with respiratory rate irregularities, higher frequency and depth of sighing, breath holding tendencies, upper-costal breathing, chest pain and slower CO_2 recovery (Wilhelm et al., 2001; Nardi et al., 2009). People with panic disorder are more sensitive to increasing CO_2 levels than those without panic disorder (Esquivel et al., 2010; Goossens et al., 2014). Administration of CO_2 causes greater activation of the anterior insular cerebral cortex in people with panic disorder compared to those without, and this is associated with increased fearful and panic feelings (Esquivel et al., 2010; Goossens et al., 2014). Taking into consideration the reports of hyperventilation and lowered CO_2 in response to stress and anxiety, increased sensitivity to rising CO_2 in people with panic disorder may indicate that the body's regulatory processes have become fatigued and have adjusted to a lower and suboptimal level of CO_2 in response to chronic hyperventilation.

Unexplained dyspnoea, possibly related to dysfunctional breathing, is associated with increased levels of anxiety (Osborne et al., 2000; Han et al., 2004) and this anxiety is greater in people with unexplained dyspnoea than in people with asthma (Han et al., 2004). As discussed above, negative emotion such as anxiety may lead to an increased respiratory rate and signs of hyperventilation. If poorly understood, hyperventilation may lead to anxiety, stimulating an increase in respiratory rate, and resulting in further hyperventilation (Gardner, 1996; Wilhelm et al., 2001; Nardi et al., 2009; Paulus, 2013). The emotional reaction to hyperventilation may be related to the perception of dyspnoea, which causes unpleasant sensations disproportional to the perceived respiratory load intensity (von Leupoldt and Dahme, 2005). However, the unpleasantness of an increased respiratory load, and resultant dyspnoea may decrease after this is reasoned not to be a threat (Zaman et al., 2014), demonstrating the cortical influence on emotion and respiration.

A stressful task while typing at the computer leads not only to an increase in respiratory rate but also increased muscle activity of the anterior scalene and upper trapezius muscles (Jaturongkhasumrit et al., 2019). People with generalised anxiety disorder report increased muscle tension which may be related to increased muscle activity during a stressful episode (Pluess et al., 2009). This increase in muscle tension and muscle activity during stressful episodes may be related to autonomic dysfunction as the sympathetic nervous system prepares the body for action and is activated by emotional and cognitive stress (Gilbert, 2014a; Hernando et al., 2016). This is supported by reports of reduced autonomic function in people who experience chronic pain (Tracy et al., 2016). This muscle dysfunction associated with stress and anxiety is likely related to hyperventilation-related biochemical changes reviewed in the previous section (section 2.5.2). Interventions using slow diaphragmatic breathing in combination with other stress-relieving strategies such as progressive muscle relaxation, guided imagery and autogenic training, reduce anxiety and stress as well as the intensity of neck pain and reported neck disability (Metikaridis et al., 2017).

The interaction between breathing, emotion and pain is confirmed in the way the brain processes and controls these variables. Breathing is influenced and changes according to input from the limbic system which is involved in emotions (Homma and Masaoka, 2008). Nose breathing causes oscillations through areas of the limbic system of the brain including the amygdala, hippocampus and piriform cortex (Zelano et al., 2016). The amygdala is involved in processing negative emotions and may play a role in the link between negative emotions and respiratory rate (Homma and Masaoka, 2008). The prelimbic medial prefrontal cortex, dorso-medial and perifornical hypothalamus, amygdala complex, and periaqueductal grey are all involved in emotion as well as controlling respiratory responses (Bondarenko et al., 2014; Kinkead et al., 2014). The medial prefrontal cortex and the periaqueductal grey also have a role to play in pain processing (Peyron et al., 2000), with the medial prefrontal cortex especially involved in chronic pain (Baliki et al., 2006). Therefore, the cortical areas active during emotion, respiratory control and pain processing overlap, showing the connection between emotion, pain and respiration.

In summary, the relationship between neck pain and breathing is complex and may have biomechanical, biochemical and psychological influences. Reduced respiratory strength, change of breathing pattern and weakness or dysfunction in respiratory muscles, contribute to the biomechanical influences. Hypercapnia and hypocapnia are examples of biochemical conditions of respiration that influence muscle dysfunction, with hyperventilation-related hypocapnia being the most well researched. Hyperventilation may be secondary to pain, but also to stress or anxiety. Respiratory rate is influenced by the autonomic nervous system which responds to stress and anxiety, as well as to pain. The areas of the brain active during respiration, emotion and pain overlap, confirming this connection. Therefore, due to the complex relationship between neck pain and breathing, multiple assessment tools should be used to assess both neck dysfunction and breathing. The assessment methods used in this research will be outlined below.

2.6 Assessment methods for neck pain and dysfunction

2.6.1 Numeric Rating Scale (NRS)

The NRS is a quick assessment tool that is valid and reliable in giving an estimate of pain (Hawker et al., 2011). The NRS shows good correlations with the visual analogue scale (Hawker et al., 2011) and is preferable to the visual analogue scale because it is easier to administer, complete and score (Hjermstad et al., 2011). The NRS is limited in that it only represents one aspect of pain (intensity) and does not give an indication of the experience of pain (Hawker et al., 2011). The NRS has moderate test-retest reliability and acceptable responsiveness in participants with neck pain (Cleland et al., 2008; Young et al., 2010).

2.6.2 Neck Disability Index (NDI)

The NDI is the most frequently evaluated questionnaire used for neck disability (Schellingerhout et al., 2011) and is commonly used to evaluate self-reported disability related to neck pain (Vernon, 2008). The NDI was modelled after the Oswestry Low Back Pain Disability Index and measures the extent that neck pain limits activities of daily living (Schellingerhout et al., 2011). Neck Disability Index (NDI) scores are higher with age until middle age (50-59 years), in females, in people experiencing neck-related arm symptoms, in people who sleep less than six hours, in those who do not exercise regularly and in those who have desk-related jobs (Kato et al., 2012).

A systematic review reported that reliability of the NDI is moderate to strong, with reliability coefficients of above 0.90 for many studies (MacDermid et al., 2009). Test-retest reliability appears to be less with acute pain (0.73-0.89) than chronic pain (0.93-0.99), but it may be used in either setting and across different populations (MacDermid et al., 2009). The NDI has excellent test-retest reliability (ICC >0.90) when tested at one time with question order or language changed (MacDermid et al., 2009). However, studies that look at reliability of the score in clinically stable patients over longer periods of time (two days to four weeks) report only fair test-retest reliability (ICC 0.50 – 0.55) (Cleland et al., 2008; Young et al., 2010).

Good construct validity and responsiveness has been reported in the literature, and this applies to acute or chronic neck pain of musculoskeletal or neural nature for various populations (MacDermid et al., 2009). This was confirmed by reports of the NDI being valid and responsive to change over four weeks in stable and clinically changing participants with neck pain (Young et al., 2010). Good responsiveness was confirmed by Jorritsma et al. (2012) who reported areas under the ROC-curve being 0.75. The NDI is reliable, internally consistent and has strong convergent and divergent validity with other tests used to assess neck pain (Vernon, 2008). It is easy to read and understand (MacDermid et al., 2009) and is recommended for clinical and research purposes (Vernon, 2008). The NDI has also been reported to address components of the International Classification of Functioning (Ferreira et al., 2010). However, there are risks for floor and ceiling effects when the score is below 10 and above 40 (MacDermid et al., 2009). The NDI has been used widely in South African studies and has been validated in Afrikaans and Zulu (Ally, 2006; le Roux 2016; Ajidahun et al., 2016).

2.6.3 Cranio-Cervical Flexion Test (CCFT)

The CCFT gives an indication of deep neck flexor muscle strength and endurance, which are often dysfunctional in people with neck pain (Jull et al., 2008). The CCFT has good intertester and intratester reliability (Chiu et al., 2005; Hudswell et al., 2005; Arumugam et al., 2011). The ICC values of two examiners performing a CCFT in asymptomatic participants was 0.91 indicating excellent intertester reliability (Arumugam et al., 2011). Intratester reliability one week apart for 10 asymptomatic participants was reported to be good (ICC 0.72) (Chiu et al., 2005). The CCFT also demonstrated good construct validity, which was confirmed by increasing activation of the deep neck flexors with progression of the CCFT (Falla et al., 2003; Jull et al., 2008).

2.7 Breathing assessments

2.7.1 Respiratory rate

An elevated respiratory rate may be a response to physiological changes in the body such as an infection, hypercapnia or increased metabolic requirements (Gilbert, 2014a). It may also be a response to pain or negative emotion (Wilhelm et al., 2001), or related to hyperventilation (Boulding et al., 2016). A normal resting respiratory rate in adults has been reported to be between 12 and 16 breaths per minute (Pryor and Prasad, 2008), and in other research between 10 and 14 breaths per minute (Bradley, 2014).

2.7.2 Cloth Tape Measure Technique (CTMT) and breathing pattern

The CTMT uses a soft tape measure around the thorax to measure thoracic expansion during a maximal inspiration. Three anatomical levels of assessment have been documented: the axilla level (upper thoracic), fourth intercostal space level (mid-thoracic), and xiphoid process level (lower thoracic) (Bockenhauer et al., 2007). The two levels most often described in the literature are the axilla and the xiphoid levels representing upper and lower thoracic expansion respectively (Bockenhauer et al., 2007; Debouche et al., 2016).

The CTMT has shown to have high intratester and intertester reliability (Mohan et al., 2012; Debouche et al., 2016) especially when a standardised method is used (Bockenhauer et al., 2007). Reported intratester ICC values are 0.919 and 0.886 and intertester ICC values are 0.847 and 0.822 for upper and lower thoracic expansion respectively (Debouche et al., 2016). LaPier et al. (2000) reported excellent reliability when the CTMT was done during a vital capacity manoeuvre with average intertester ICC values of 0.90 to 0.97 and intratester ICC values of 0.89 to 0.97 for upper and lower thoracic expansion respectively.

Thoracic expansion may be influenced by sex and age (Kaneko and Horie, 2012). Females expand more through the thorax and less through the abdomen (Ragnarsdóttir and Kristinsdótter, 2005; Kaneko and Horie, 2012; Da Gama et al., 2013; Takashima et al., 2017) and males generally have greater overall expansion (Adedoyin et al., 2012; Kaneko and Horie, 2012). Thoracic mobility generally decreases with age (Ragnarsdóttir and Kristinsdótter, 2005; Adedoyin et al., 2012; Kaneko and Horie, 2012; Szczygiel et al., 2014), especially in males (Adedoyin et al., 2012).

Thoracic expansion at both upper and lower levels correlate significantly with respiratory function and inspiratory strength (de Cordoba Lanza et al., 2013; Debouche et al., 2016). Lower thoracic expansion is correlated with FEV_1 ($r=0.544$, $p < 0.001$; $r=0.48$, $p<0.0001$), FVC ($r=0.503$, $p < 0.001$; $r=0.50$, $p < 0.0001$), VC ($r=0.537$, $p<0.001$), maximum inspiratory pressure ($r=0.430$, $p = 0.002$; $r=0.46$, $p < 0.001$) and inspiratory capacity ($r=0.405$, $p=0.002$; $r=0.39$, $p=0.02$) (de Cordoba Lanza et al., 2013; Debouche et al., 2016). Upper thoracic expansion is correlated with FEV_1 (r=0.322, p=0.024; r=0.30, p=0.017), FVC (r=0.322, p=0.017; r=0.32, p=0.009), VC (r=0.349, p=0.010), maximum inspiratory pressure (r=0.330, p =0.019; r=0.48, p<0.0001) and inspiratory capacity (r=0.267, p=0.051; r=0.24, p=0.012) (de Cordoba Lanza et al., 2013; Debouche et al., 2016). Lower thoracic expansion is correlated more strongly with respiratory function and respiratory strength than upper thoracic expansion (de Cordoba Lanza et al., 2013; Debouche et al., 2016).

In this study, the CTMT was adapted to include thoracic expansion during tidal breathing. Literature evaluating thoracic expansion or movement during quiet breathing using various three-dimensional movement capturing equipment have reported that quiet breathing expansion is less than a third of deep breathing (Kaneko and Horie, 2012).

Breathing pattern is generally not a conscious action and therefore, although it may correspond to CTMT during deep breathing (Halim et al., 2016), it is important that breathing pattern is determined during quiet breathing. Breathing pattern in the current study was determined by the ratio of lower and upper thoracic CTMT during quiet breathing, which is yet to be validated.

2.7.3 Nijmegen Questionnaire (NQ)

The NQ is a subjective measure of dysfunctional breathing (van Dixhoorn and Folgering, 2015). The NQ questions give an indication of respiratory-related stress and anxiety, and symptoms associated with hypocapnia or breathing difficulty (Courtney and van Dixhoorn, 2014; van Dixhoorn and Folgering, 2015).

The NQ was validated to be highly sensitive and specific to hyperventilation syndrome using the hyperventilation provocation test (van Dixhoorn and Duivenvoorden, 1985), and more recent studies have reported good content validity, based on reported symptoms by clinicians and patients with experience of hyperventilation (Li Ogilvie et al., 2019). However, there are inconsistent reports of NQ scores corresponding with hypocapnia (Courtney et al., 2011; van Dixhoorn and Folgering, 2015). The NQ has poor structural validity with there being discrimination and sex bias for some of the questions, and there were many reported symptoms of hyperventilation not included in the NQ (Li Ogilvie et al., 2019). High NQ scores are also associated with non-respiratory related conditions such as chronic pain and anxiety, possibly related to high sympathetic tone (Courtney and van Dixhoorn, 2014). Therefore, the NQ should be used as a general screening tool for medically unexplained conditions and anxiety-related breathing problems (Bradley and Esformes, 2014; van Dixhoorn and Folgering, 2015).

Test-retest reliability has been stated to be fair to good (ICC 0.87) (van Doorn et al., 1983; Li Ogilvie et al., 2015). The NQ shows good responsiveness to change following treatment for a range of respiratory and non-respiratory complaints (Courtney and van Dixhoorn, 2014). The NQ has been reported to correlate negatively with BHT (r=-0.317; p-0.02) (Courtney and Cohen, 2008) and positively with SEBQ scores (r=0.75; p=0.0001) (Courtney et al., 2011). The questionnaire is easy and quick to complete (Courtney and van

Dixhoorn, 2014; Li Ogilvie et al., 2015). It is still widely used, despite the lack of good validity and reliability studies, and is the only questionnaire used to diagnose hyperventilation (Li Ogilvie et al., 2015). The NQ has been used in the South African context evaluating hyperventilation symptoms among people with human immunodeficiency virus (Reychler et al., 2017). It was reported in their study that this immunocompromised population had higher NQ scores than the average scores in other populations. They did not report any limitations with the questionnaire in the South African context.

2.7.4 Self-Evaluation of Breathing Questionnaire (SEBQ)

The SEBQ is a self-administered questionnaire that has been developed in the last ten years based on symptoms of dysfunctional breathing in the literature (Courtney and Greenwood, 2009). The questionnaire gives an indication of the quality and quantity of respiratory discomfort as well as the participant's perception of this discomfort (Courtney and van Dixhoorn, 2014). The SEBQ incorporates two factors of breathing: "lack of air" and "perception of inappropriate or restricted breathing" (Courtney and Greenwood, 2009). The SEBQ is positively associated with the NQ (r=0.75, p=0.0001) and FEV_1 (r=-0.264, p=0.02) (Courtney et al., 2011). However, when the SEBQ was analysed as a two-factor questionnaire, the NQ was found to correlate only to the first factor (r=0.338, p=0.002) and not to the second (r=0.166, p=0.134) (Courtney and Greenwood, 2009). Therefore, the SEBQ may be helpful in identifying elements of dysfunctional breathing not included in the NQ (Courtney and Greenwood, 2009). The SEBQ has good test-retest reliability (ICC 0.89) and internal consistency (Cronbach's α = 0.93) in the general population, and is associated with the female sex, self-reported respiratory problems, recent respiratory infection, and current smoking (Mitchell et al., 2016). To the researcher's knowledge this is the first study that has used the SEBQ in a South African population.

2.7.5 Breath hold time (BHT)

Breath hold time (BHT) is a test based on the Buteyko Breathing Technique of breathing where the breath is held at the functional residual volume (Courtney and Cohen, 2008; Courtney, 2014). The original Buteyko BHT test assumed that the time a person could hold their breath was positively correlated to the arterial CO_2 levels (Courtney and Cohen, 2008; Courtney, 2014) and has been used in the diagnosis of hyperventilation syndrome (Warburton and Jack, 2006). The measure of BHT as a diagnostic tool for hyperventilation is not consistent in the literature with some studies reporting reduced BHT in participants with hypocapnia (Jack et al., 2004) and others reporting no significant difference in BHT between those with hypocapnia and those with normocapnia (Kiesel et al., 2017). No significant correlation has been found between BHT and end-tidal CO_2 (r=-0.107, p=0.580; r=-0.198, p=0.07) (Courtney and Cohen, 2008; Courtney et al., 2011). Therefore, it has been suggested that a low BHT may be a result of a combination of factors including hypocapnia, mechanical feedback from the diaphragm and psychological factors, indicating a problem in either biomechanical, biochemical or psychological aspects of breathing (Courtney and Cohen, 2008; Courtney, 2014).

A low BHT was found to be associated with upper-costal breathing (r=-0.408, p=0.028; r=-0.25, p=0.02) and reduced FEV_1 (r=0.31, p=0.005) but not with the NQ (r=0.156, p=0.418; r=-0.18, p=0.10), SEBQ (r=0.122, p=0.528; r=-0.20, p=0.07) or respiratory rate (r=-0.210, p=0.275; r=-0.16, p=0.14) (Courtney and Cohen 2008; Courtney et al., 2011). One study reported no significant difference in BHT between people diagnosed with dysfunctional breathing (upper-costal breathing pattern, high NQ or SEBQ scores) compared with controls (Kiesel et al., 2017). It has been reported that people with panic disorder have reduced BHT, possibly due to hypocapnia and hyperventilation (Nardi et al., 2009).

BHT is reduced with respiratory or cardiac pathology; therefore, it is important to exclude other pathology before attributing a low BHT to dysfunctional breathing (Warburton and Jack, 2006). People with lung disease and asthma show a greater reduction in BHT than those with unexplained dyspnoea (Han et al., 2004). BHT can be improved in healthy people with acute voluntary hyperventilation and oxygen treatment. However, those experiencing unexplained dyspnoea, anxiety or hyperventilation symptoms show no improvement of BHT following voluntary hyperventilation or oxygen treatment (Han et al., 2004; Jack et al., 2003). Breath Hold Time (BHT) as well as symptoms of dysfunctional breathing improve with specific breathing retraining in those who report unexplained dyspnoea (Han et al., 2004).

2.8 Assessment of muscle activity

2.8.1 Surface electromyography (sEMG)

Electromyography is a way of quantifying the electrical potential of a muscle over time which provides an estimated value for muscle contraction or activation (Norali and Som, 2009). There are three types of electrodes commonly used: wire, needle and surface electrodes. Surface electrodes are the least invasive and are commonly used in clinical and research settings (Norali and Som, 2009). Surface electromyography (sEMG) uses biosignals to determine the average muscle contraction over time (Norali and Som, 2009).

Each muscle is made up of motor units which consist of a variable number of muscle fibres innervated by the same motor neuron (Naik et al., 2016). These muscle fibres may be distributed across the cross-section of the muscle (Naik et al., 2016). The number of motor units that participate in a muscle contraction depends on the type of contraction and the force required (Naik et al., 2016). Motor neurons stimulate the muscle fibres of their motor unit and this results in a motor nerve and a motor unit action potential (Naik et al., 2016). The sEMG picks up the electrical activity from the motor unit action potentials created during this process and gives a summary over a set time-period for a specific area (Naik et al., 2016).

Various factors can influence the readings of sEMG including electrode size and shape, distance between electrodes, location of electrodes and proximity to innervation zones or musculo-tendinous junctions, thickness of skin and adipose tissue, alignment of electrodes in relation to muscle fibre direction, muscle fibre conduction velocity, muscle properties including the number of motor units or fibre size and type of muscle unit in the area, blood flow and temperature of the area, metabolic production, intramuscular pH, ion concentrations and shifts across muscle cell membranes, and type of muscle contraction (Merletti et al., 2001). Therefore, the signal amplitude should be interpreted with caution. Inspiration velocity may be influenced by an increased respiratory rate, causing an increase in sEMG measurements of the scalene and sternocleidomastoid muscles (Costa et al., 1997). Readings are also more reliable when the electrodes are placed away from the zone of innervation which differs between muscles (Merletti et al., 2001). De Luca et al. (2011) reported that an inter-electrode distance of 10 mm was the best electrode distance to minimise crosstalk and provide reliable signal amplitude readings during gait and isometric contractions.

Surface electromyography (sEMG) for the sternocleidomastoid and anterior scalene muscles has good reliability and repeatability (ICC > 0.65 and ICC > 0.75 respectively) when measured during an isometric contraction in the supine position (Falla et al., 2002a). During a functional task (ironing, turning head and shoulder abduction) in standing, sEMG of the sternocleidomastoid was reported to have good reliability (ICC > 0.7) for frequency and amplitude but not for muscle unit recruitment (Kallenberg et al., 2009).

2.9 Assessment of perceived stress

2.9.1 Perceived Stress Scale (PSS)

The PSS evaluates two main perceptions: perceived helplessness, which gives an indication of general distress due to overwhelming or uncontrollable circumstances, and perceived self-efficacy, which gives an indication of the person’s ability to cope with their circumstances (Roberti et al., 2006; Lavoie and Douglas, 2012; Smith et al., 2014; Taylor, 2015; Lee and Jeong, 2019). These factors are consistent between sexes and between people with a clinical psychological diagnosis and those in the community (Lavoie and Douglas, 2012). The PSS is moderately to strongly correlated with other measures of anxiety and depression (Lee, 2012). Scores are lower for younger people, people who are married, employed and earning a high income (Lee, 2012). Scores are higher in parents who have many children or chronically ill children as well as people who report reduced health, who smoke, and have help-seeking tendencies (Cohen et al., 1983; Lee, 2012). The reliability of the test is good with average Cronbach’s alpha values of greater than 0.70 for the PSS-10 and the test-retest reliability is also greater than 0.70 (Lee, 2012). The PSS is recommended for clinical and research purposes (Lee, 2012).

In a South African survey, mean perceived stress scores were 18.6 (±6.7) (Hamad et al., 2008). In their study, an increased PSS was associated with female gender, increased household members, being of race other than African or Caucasian, lower income or unemployment, lower self-perceived placement on community, and the occurrence of a birth or trauma. They did not report any limitations with this questionnaire in the South African context.

2.10 Conclusion of the literature review

In conclusion, neck pain is a common problem with high levels of chronicity and recurrence. The highest risk factors for neck pain include psychosocial factors, being female, and having previous neck pain. These factors also affect prognosis. Neck pain is associated with an upper-costal breathing pattern and hypocapnia as well as reduced thoracic expansion, respiratory function and respiratory strength. When there are changes in breathing that are sub-optimal and not related to other pathology, this is termed dysfunctional breathing. Dysfunctional breathing has three dimensions, biomechanical, biochemical and psychological, which may all contribute towards the relationship between neck pain and breathing. The way in which neck pain is related to breathing from the perspective of these three dimensions has been comprehensibly discussed. Assessment of dysfunctional breathing should be multidimensional and consist of both subjective and objective tests. Various assessment methods used to evaluate neck pain and neck dysfunction (NRS, NDI, CCFT) as well as breathing (respiratory rate, CTMT, NQ, SEBQ, BHT) have been discussed in detail. Surface electromyography (sEMG) and the PSS have been reviewed in their assessment of muscle activity and perceived stress respectively.

3 METHODOLOGY

This chapter describes the methodology of the research. It includes the study design, setting, source of participants, sample size calculation method and explanation, sample selection with inclusion and exclusion criteria, explanation and interpretation of the instrumentation and outcome measures used, the procedure methods, ethical considerations and data analysis.

3.1 Study design

This study is a quantitative cross-sectional analytical study. The researcher investigated breathing outcomes at the same time as evaluating neck pain intensity, neck disability, deep neck flexor strength, sEMG and perceived stress. These assessments were done for participants with neck pain at a time when they were experiencing neck pain and for the control group at a time where they had no neck, shoulder or thoracic pain. The research was done in accordance with the Strobe guidelines for an observational cross-sectional study (Vandenbroucke et al., 2007).

3.2 Study setting

This research was done in Johannesburg, South Africa through the University of Witwatersrand. Most of the testing took place at two facilities of the physiotherapy private practice where the researcher works. Additional assessments were done in and around the Johannesburg area, at the researcher and the participants' houses or workspace. Assessments were done between 01 July 2019 and 14 December 2019. Each assessment session was 45 minutes long.

3.3 Participants

3.3.1 Source of participants

The neck pain group was recruited mainly through the private physiotherapy practice where the researcher was working. Participants from the general public of Johannesburg, South Africa, were recruited through a public Facebook post and word of mouth. Details of participant recruitment can be found in the procedure of the dissertation (section 3.5.2). Participants were included in the neck pain group if they were currently experiencing neck pain, met the criteria for the neck pain group and consented to be assessed. The control group were volunteers from the physiotherapy practice or general public without neck pain who met the criteria and were matched in age (±5 years) and sex to the neck pain group. Patients attending physiotherapy were only included in the control group if they were being seen for complaints other than neck pain, neck-related headache, shoulder, thoracic or chest complaints.

3.3.2 Sample size

As there is no previous literature evaluating a range of respiratory outcomes in participants with neck pain, a sample size was calculated based on the differences of MVV means between participants with neck pain and healthy controls in the study done by Dimitriadis et al. (2014). The MVV is suggested to be the most important respiratory function measure in people with neck pain (Dimitriadis et al., 2016). It is a general measure of respiratory function which includes respiratory muscle function, ventilatory control and chest wall compliance (Dimitriadis et al., 2014; Dimitriadis et al., 2016). Due to the researcher wanting to assess multiple aspects of breathing, it was reasoned that a general measure of respiratory function would be used on the basis on which to predict outcomes. Other studies that investigated breathing in people with neck pain either had very small sample sizes (Kapreli et al., 2009; Wirth et al., 2014) or measured very specific respiratory outcomes (Halim et al., 2016). A significant difference in MVV means were reported in Dimitriadis et al. (2014) indicating that participants with neck pain had reduced respiratory function compared to participants without neck pain. By looking at the difference in MVV means reported in Dimitriadis et al. (2014), the expected difference in respiratory outcomes for the current study was predicted and the sample size necessary to be confident in this difference could be calculated. The means of MVV in participants with neck pain and those without were reported to be 92.2 and 104.4 respectively, with a standard deviation of 21.2 (Dimitriadis et al., 2014). Using these values, a sample size of 48 was recommended to achieve a 95% confidence interval and power of 80%. Figure 3-1 illustrates the method of calculation used to determine the sample size:

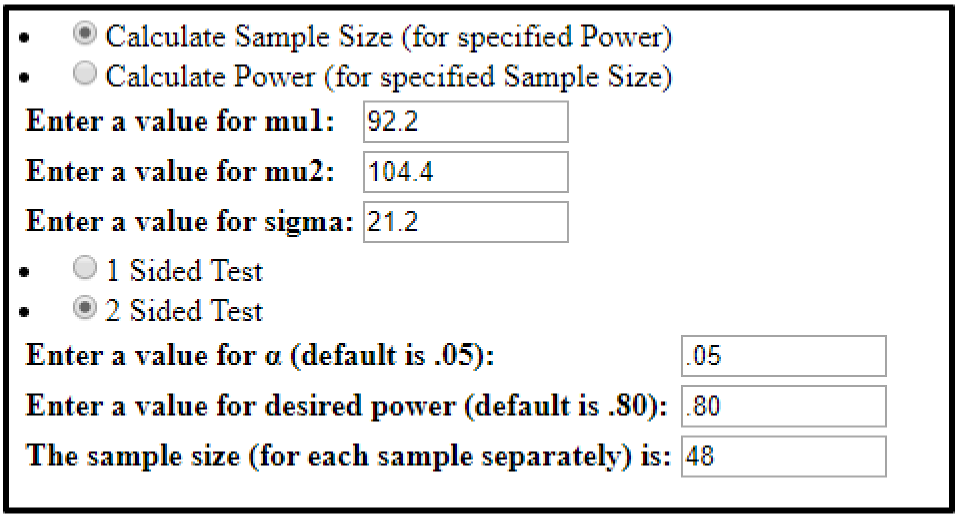

Figure 3-1: Sample size calculation

The researcher recruited 49 people who all met the criteria. This was more than what was required for statistical significance. She hoped that by including more than the minimum number, this would strengthen the statistical analysis and would account for any participants dropping out.

3.3.3 Sample selection

Subjects were selected by a convenient sampling selection method. Table 3-1 and Table 3-2 show inclusion and exclusion criteria respectively. The reasons for the exclusion criteria will be outlined below the tables.

Table 3-1: Inclusion criteria

Neck pain group	Control group
• Pain in the neck area of insidious onset (with or without shoulder, thoracic or arm pain)	• People without neck pain
• 20 – 60 years of age	

Table 3-2: Exclusion criteria

Neck pain group	Control group
• Traumatic cause of neck pain • More than one physiotherapy treatment session for the neck, shoulder or thoracic spine in the last week	• Neck pain in the last six months • Current pathology/pain in the following areas: shoulder, thorax, chest • Headache with associated neck pain or of suspected neck origin
• Previous surgery of the spine, thorax and upper abdomen • Lung, cardiac or neuromuscular pathology (excluding asthma) • One or more asthma attack in the last 6 months • Current infection • Current smoking habit	

The researcher excluded people with neck pain of traumatic onset because she was interested in neck pain related to, and possibly caused by, stress and dysfunctional breathing, and wanted to limit other contributing causes for neck pain. Likewise, participants who had had surgeries of the spine, thorax and upper abdomen as well as those with lung, cardiac and neuromuscular disorders were excluded from the study as reduced mobility or muscle dysfunction in these areas could influence breathing mechanics, muscle activity and spinal stability. Participants were excluded if they had had a recent asthma attack (in the last 6 months) or were current (regular) smokers as this would influence breathing mechanics and symptoms. Participants were also excluded if they were experiencing any type of known current infection, as this may cause systemic effects such as an increase in respiratory rate or a heightened perception of pain. Participants were excluded if they had received more than one physiotherapy treatment in the preceding week to minimise treatment effect on the testing. Due to the recurrent and often chronic nature of neck pain, participants were excluded from the control group if they had experienced neck pain in the preceding six months. Dysfunction in the neck may also result in referred pain to areas such as the shoulder, chest, thoracic spine or head. Therefore, participants were excluded from the control group if they had pain or pathology in these areas.

3.4 Instrumentation and outcome measures

A summary of the assessment tools used, and the variables measured can be found in Table 3-3 and Table 3-4. Each assessment tool is explained fully with regard to its use and interpretation. The specific method of how each test was carried out in the present study will be covered in section 3.5.2. The reliability and validity of each measuring instrument is discussed in the literature review. All the tests and questionnaires were given and instructed to the participants in English.

Table 3-3: Summary of questionnaires

Questionnaire	Outcomes measured	Variable	Appendix
Numeric Rating Scale	Pain intensity	Neck pain and neck disability: Independent	H
Neck Disability Index	Gives an indication of the extent that neck pain limits daily activities		I
Nijmegen Questionnaire	Subjective indication of dysfunctional breathing related to psychological and biochemical symptoms	Self-reported symptoms of dysfunctional breathing: Dependent	J
Self-Evaluation of Breathing Questionnaire	Subjective indication of dysfunctional breathing related to biomechanical and biochemical symptoms		K
Perceived Stress Scale	Subjective perception of stress. May overlap with aspects of anxiety and depression. Main components: perceived helplessness and self-efficacy	Psychological: Explanatory	L
Researcher's Questionnaire	— Presence of asthma or chest problems — Presence of allergies or sinus problems — Frequency and type of exercise — Hours spent on a computer	Confounding	H

Table 3-4: Summary of physical tests

Assessment	**Outcomes measured**	**Variable**
Cranio-Cervical Flexion Test	Deep neck flexor strength, control and endurance	Neck stabiliser strength: Dependent
Cloth Tape Measure Technique	Thoracic expansion and breathing pattern	Respiration: Dependent
Respiratory rate	Tachypnoea, bradypnea or normal respiratory rate indicating respiratory control and its response to varied stimuli	
Breath Hold Time	Breath control influenced by biomechanical, biochemical and psychological aspects	Dysfunctional breathing: Dependent
Surface electromyography	Electrical signals from skeletal muscles (sternocleidomastoid and anterior scalene)	Muscle activity: Dependent
Body mass index	Gives an indication of appropriate weight for height	BMI: Confounding

3.4.1 Numeric Rating Scale (NRS) and Neck Disability Index (NDI)

The NRS (Appendix H) and NDI (Appendix I) are commonly used measures for neck pain giving a self-reported indication of pain intensity and disability, respectively.

The NRS is an 11-point scale on which the participant is asked to rate their pain from zero to 10, where zero indicates no pain and 10 indicates the "worst pain imaginable" (Hawker et al., 2011). This is commonly presented on a line where increments of whole numbers are shown and the participant chooses the whole number that best represents their pain either currently or in the past 24 hours (Hawker et al., 2011). Recommended cut-offs used in the current study are: 0-5 indicating mild pain, 6-7 moderate pain and 8-10 severe pain (Boonstra et al., 2016). These categories are relevant for the general population of people with musculoskeletal pain as well as for people with high catastrophising tendencies (Boonstra et al., 2016). However, for those who have low catastrophising tendencies, categories are slightly lower: 0-3 mild, 4-6 moderate and 7-10 severe (Boonstra et al., 2016).

The NDI is a self-rating questionnaire assessing the extent that neck pain is affecting everyday activities. There are ten sections regarding different activities with the option of scoring zero to five in each section. The five options in each section are based on various descriptions regarding how the neck pain may be limiting that activity. The overall score is out of 50 and was interpreted in this study as follows: 0-4 no disability, 5-14 mild disability, 15-24 moderate disability, 25-34 severe disability and 35-50 complete disability (Vernon, 2008). A cut-off of 15 has been recommended as being the most sensitive and specific for detecting disability that limits activity and causes health-seeking behaviour (Kato et al., 2012).

3.4.2 Nijmegen Questionnaire (NQ)

The NQ (Appendix J) is the most commonly used and best documented questionnaire in the diagnosis of hyperventilation and, more recently, dysfunctional breathing (Courtney et al., 2011; van Dixhoorn and Folgering, 2015).

The NQ consists of 16 symptom-related questions which are answered on a five-point scale from zero (never) to four (very often). The total score is out of 64. Normal values in healthy individuals have reported to average between five and eleven (Courtney et al., 2011; Han et al., 2004; Thomas et al., 2005). The literature is unclear as to what is considered positive for classification of dysfunctional breathing with some suggesting a score of 20 and above (Courtney and van Dixhoorn, 2014; van Dixhoorn and Folgering, 2015) and others using 23 as a cut-off value (van Dixhoorn and Duivenvoorden, 1985; Agahe et al., 2012; Kiesel et al., 2017; Ok et al., 2018). In the current study a cut-off of 23 was used in the classification of Dysfunctional Breathing, as was originally described in van Dixhoorn and Duivenvoorden (1985).

3.4.3 The Self-Evaluation of Breathing Questionnaire (SEBQ)

The SEBQ (Appendix K) is a self-administered questionnaire that has been developed in the last ten years based on reported symptoms of dysfunctional breathing found in the literature (Courtney and Greenwood, 2009).

The most recent version consists of 25 statements relating to dysfunctional breathing symptoms which are rated on a four-point scale from zero (never/not true at all) to three (very frequently/very true) (Mitchell et al., 2016). There are limited normative values for the SEBQ, however, based on studies that have compared NQ scores with SEBQ results, a suggested cut-off of 11 was used for the classification of dysfunctional breathing (Courtney et al., 2011).

3.4.4 Perceived Stress Scale (PSS)

A few versions of the PSS exist. A commonly used version with good psychometric properties is the PSS-10. The PSS-10 (Appendix L) is a short and easy-to-use questionnaire measuring general stress (Lee, 2012).

The questionnaire has 10 statements and the participant is asked to rate each question on a five-point scale from zero (never) to four (very often). When calculating the score out of 40, questions 4,5,7 and 8 are to be reversed as they are phrased in the positive, whereas the others are phrased in the negative (Cohen et al., 1983). The PSS has not been validated as a diagnostic tool and has no validated cut-off values. However, a higher score indicates greater perceived stress (Smith et al., 2014). Stress was not categorised in this study and the results were interpreted in relation to other results. This questionnaire was used to assess the impact of general stress on neck pain, neck disability, muscle dysfunction and respiration.

3.4.5 Cranio-Cervical Flexion Test (CCFT)

The CCFT is used to measure strength and endurance of the deep neck flexor muscles. The most commonly used and documented method of performing the CCFT is found in Jull et al. (2008). During this test, a biofeedback cuff is placed under the neck of the participants while they lie in crook-lying. The person undergoing the test is required to increase the pressure in increments of 2 mmHg from 20 mmHg to 30 mmHg by tucking their chin in and pushing their neck into the cuff, holding each increment for ten seconds. The pressure at which the participant can perform 10 sets of 10-second holds with good control and minimal superficial muscle recruitment is recorded (Jull et al., 2008). The higher the pressure the participant can hold, the better the strength and endurance of their deep neck flexors. This test was done using a Chattanooga Stabiliser Pressure Biofeedback Device.

3.4.6 Cloth Tape Measure Technique (CTMT) and breathing pattern

The CTMT is a simple measure of thoracic expansion using a soft measuring tape. The CTMT is normally used to measure the difference between maximal inspiration and expiration in standing. For this study, it was adapted to measure thoracic expansion in sitting not only during maximum breathing but also quiet breathing (see section 3.5.2.2). The CTMT gives an indication of respiratory function and strength (de Cordoba Lanza et al., 2013; Debouche et al., 2016).

Thoracic expansion using CTMT in healthy adults has been reported to be between 1.5 cm and 9.6 cm at the axilla level and between 2.3 cm and 11.7 cm at the xiphoid level (Debouche et al., 2016). Another study reported thoracic expansion between 1 cm and 7 cm at the axilla level and between 1.5 cm and 7.8 cm at the xiphoid level (Bockenhauer et al., 2007). Both these studies reported significantly greater lower thoracic expansion than upper thoracic expansion for healthy individuals (Bockenhauer et al., 2007; Debouche et al., 2016). Adedoyin et al. (2012) reports upper thoracic expansion to be between 1.5 cm and 5.2 cm for males and between 1.3 cm and 4.9 cm for females, and lower thoracic expansion between 1.3 cm and 4.9 cm for males and between 0.9 cm and 3.6 cm for females.

Normal expansion during quiet breathing is between 0 cm to 1 cm for the upper thoracic and between 0.1 cm to 1 cm in the lower thoracic area (Ragnarsdóttir and Kristinsdótter, 2005). Abdominal movement is greater than thoracic movement for quiet and deep breathing, regardless of age, sex, or posture (supine or sitting) (Kaneko and Horie, 2012; Szczygiel et al., 2014). Thoracic expansion results were not analysed independently but were interpreted in relation to other results.

Breathing pattern was determined by the ratio of lower and upper thoracic expansion during quiet and deep breathing as measured with the CTMT. When lateral expansion of the lower thoracic and abdomen exceeds upper thoracic expansion, this is costo-diaphragmatic breathing and when upper thoracic expansion is greater than abdominal and lateral costal expansion, this is termed upper-costal breathing (Celhay et al., 2015).

3.4.7 Respiratory Rate

An elevated respiratory rate may be associated with acute hyperventilation, pain, anxiety or infection (Wilhelm et al., 2001; Boulding et al., 2016). Normal respiratory rate for adults is between 12 and 16 breaths per minute (Pryor and Prasad, 2008). Other literature suggest that normal respiratory rate is between 10 and 14 breaths per minute (Bradley, 2014). A respiratory rate in adults of more than 20 breaths per minute is considered tachypnoea and below 10 breaths per minute, bradypnea (Pryor and Prasad, 2008). In this study an abnormal respiratory rate was classified as either above 20 breaths per minute or below 10 breaths per minute.

3.4.8 Breath Hold Time (BHT)

BHT is the time a person can hold their breath at functional residual capacity based on the Buteyko Breathing Technique. A low BHT may be indicative of hypocapnia, anxiety or diaphragmatic sensory feedback, suggesting a problem in either biomechanical, biochemical or psychological aspects of breathing (Courtney and Cohen, 2008; Courtney, 2014).

A BHT less than 20 seconds may be seen as mildly suggestive of dysfunctional breathing and less than 10 seconds strongly suggestive of dysfunctional breathing (Warburton and Jack, 2006). In the current study a BHT of less than 20 was used in the classification of dysfunctional breathing.

3.4.9 Surface Electromyography (sEMG)

Surface electromyography (sEMG) is a commonly used non-invasive way of measuring muscle activity. The method of measuring and recording sEMG was adapted from the recommendations of Falla et al. (2002b) for the sternal head of sternocleidomastoid and anterior scalene muscles (see section 3.5.2.3). Previous studies have shown that the activity of the sternal and clavicular head of the sternocleidomastoid are not significantly different (Campbell 1955) and that with breathing the muscle activity of the right and left sides of the neck were similar (Costa et al., 1997), therefore the sternal head of the sternocleidomastoid was measured and both muscles were evaluated on the left side of the neck. A NeuroTrac MyoPlus2 (Verity Medical Ltd.) was used. The setting for EMG on the NeuroTrac MyoPlus2 ranges between 0.2 μV and 2000 μV and has a sensitivity of 0.1 μV RMS and an accuracy of 4% of μV reading (± 0.3 uV) at 200 Hz. A Wide range frequency was used during this study which has been shown to be more accurate and has a range between 18Hz (± 4 Hz) and 370 Hz (±10%) when reading below 235 μV.

3.5 Procedure

3.5.1 Pilot study

The pilot study consisted of five participants with current neck pain and five sex and age (±5 years) matched controls without neck pain. These participants were chosen according to the inclusion and exclusion criteria for the neck pain and control groups. Participants were sourced from the general public and from the private physiotherapy practice where the researcher worked. Participants in the pilot study were asked to fill out a feedback form so that improvements could be made. As a result of these comments and other limitations the researcher encountered, some changes were made to the original study proposal during this period. Firstly, it was decided that the researcher would be able to complete data collection without the help of an assistant. This decision was made based on the necessity of collecting data at relatively short notice to minimise possible effects of physiotherapy treatment. The independence of the researcher during data collection also allowed her to arrange data collection sessions at any time of day according to the participants' schedules. There were a few other changes that were made to the original proposal that are outlined in Table 3-5 below.

Table 3-5: Limitations and changes made to the study

	Limitation	Relevant adjustment
Researcher's Questionnaire	Questions did not screen for exclusion criteria and were not specific.	Additional questions were included regarding exclusion criteria (smoking, whiplash) and existing questions were explained or worded more clearly (allergies and surgeries).
Other questionnaires	Some of the questionnaires in their downloadable formats had places for names and scoring. They also were not uniform in font or sizing which made the data pack look untidy.	Places for names or score totals were removed so that it was clear to the participant that their name was not required on the questionnaires and they did not have to calculate their own score. The font and formatting were also adjusted to make the questionnaires more uniform without changing wording, scoring or interpretation.

CCFT	For some participants with long necks the cuff shifted down the neck during the exercise, which could influence the results.	For participants with long necks, an empty pillowcase was placed under the lower cervical spine so that the cuff remained in its position at the upper cervical spine.
	To hold the biofeedback in a good position without arm fatigue was challenging.	A pillow was placed on the participants' abdomen/chest area and they were encouraged to rest their arms on the pillow so that it did not affect the shoulder muscles and they could hold the feedback device comfortably.
CTMT	The researcher could not measure and record while maintaining hand and tape measure positioning.	A voice recording was made of the measurement readings with the researcher's cell phone which were then captured on the data recording sheet after the assessment had been completed.
Respiratory rate	Observing respiratory rate during the completion of questionnaires proved difficult if the participant wanted to ask questions. Their sitting posture over the treatment table also impeded clear observation of the abdomen and chest movement.	Observation of respiratory rate was done instead during the recording of sEMG for quiet breathing. During this time the participant was relaxed and looking forward which made observation of respiratory rate easier.
	An irregular respiratory rate may be present in people with dysfunctional breathing, therefore measuring respiratory rate over 30 seconds may not be adequate.	Respiratory rate was observed and recorded over 60 seconds.
BHT	The researcher was concerned that BHT was not always completely in sync with the participants' breath.	The participant was asked to time the breath-hold as a second timer. If there was a difference of more than one second, the trial was repeated.
sEMG	The original protocol included sEMG of the upper trapezius. The upper trapezius is listed as an accessory muscle but is not as frequently utilised for breathing as the	It was decided to measure the muscle activity of the sternocleidomastoid and the anterior scalene as this was consistent with other literature and was the best documented.

	sternocleidomastoid and scalene muscles. The sEMG machine used for the study could only measure two muscles at a time. Changing the position and settings twice would add unnecessary time to the assessment.	
	It was noticed that there was a variation in muscle activity when measurements were repeated, and the researcher was concerned that the time allocated to measuring sEMG would not be accurate.	Two trials of deep breaths (three breaths in each trial) were done for deep breathing measurements and sEMG measurement for quiet breathing was changed from 30 seconds to 60 seconds.

3.5.2 Main study

Permission from the management of the physiotherapy practice where the researcher worked was obtained. Information about the research was presented to the physiotherapists working at the practice and the inclusion and exclusion criteria were explained. The neck pain group was recruited from two facilities of this private physiotherapy practice as well as from the general public. The researcher asked her colleagues to screen all their patients for possible volunteers who met the inclusion and exclusion criteria and she did the same for her patients. If they met the criteria, they were invited to participate in the study by the treating physiotherapist. To avoid coercion bias, the researcher made it clear that refusing to participate in the study would in no way impact their quality of treatment and that they could withdraw at any point without repercussions. The potential volunteers for the neck pain group were informed that assessment needed to take place while they were experiencing neck pain, but they were not given a time frame in which they were required to schedule the meeting. People from the general public were recruited through word of mouth as well as through a Facebook post on the researcher’s Facebook page inviting people to participate. The control group was recruited from the general public through word of mouth. Patients who were not being treated for neck, shoulder, thoracic or chest complaints were invited to be part of the control group if they met the inclusion and exclusion criteria. The control group were matched in age (± 5 years) and sex to the neck pain group.

Once the invitation to participate had been accepted, a convenient place and time was organised for the researcher to meet the participant for the assessment. For most participants, data collection took place at one of the private physiotherapy facilities where the researcher was working, in Johannesburg South Africa.

Both groups were required to do the same tests, except for the NDI and NRS which the control group was not required to complete as they were not appropriate. The assessments were done in the same order for every participant. To avoid bias, the researcher gave a standardised instruction to all the participants and ensured that tests were carried out in a standardised way. However, the researcher was not blinded to the groups (see section 6.3). She was involved in both the recruitment of the participants, and the testing. This was necessary as testing occurred at relatively short notice. Many of the tests did not lend themselves to bias from lack of blinding as they were objective. Having the researcher, who was familiar with the physical tests, assess every participant improved the testing reliability of the study. The procedure for the assessment of both groups is explained in detail below.

3.5.2.1 Consent, questionnaires and body mass index (BMI)

The participants were required to read an information sheet (or have the study explained to them if they preferred) and sign a consent form before they were able to commence with the assessment. The researcher outlined what was required from the participant and was available to answer any questions the participant had before and during the assessment. Once the participant had consented, they were asked to fill out the relevant questionnaires including the researcher's questionnaire, NDI, NQ, SEBQ and PSS. The researcher's questionnaire contained questions relating to the inclusion criteria, exclusion criteria and confounding variables. The NRS was also featured on this questionnaire. The control group were not required to fill in the NRS section of the researcher's questionnaire nor the NDI. Participants with neck pain completed all five questionnaires.

Before the physical tests were done, height and weight were obtained from the participant verbally unless they did not know these parameters, in which case they were measured using a scale and height tape measure, both of which were available at the private physiotherapy facilities. If the assessment venue had no scale or height measuring facility, the researcher used her cloth tape measure to obtain height with the participant standing against a wall, and the participant was requested to send their weight to the researcher once it was obtained. Once height and weight were obtained, the BMI was calculated and recorded on the recording sheet. The remainder of the session consisted of physical tests which will be outlined below in the order in which they were assessed.

3.5.2.2 Cloth Tape Measure Technique (CTMT)

The CTMT was used to measure thoracic expansion at axilla and xiphoid levels while the patient was in a sitting position. The participant was asked to remove their jacket or jersey; however, the researcher did not require their shirt to be removed. This method was adapted from Bockenhauer et al. (2007) for upper and lower thoracic expansion to include quiet breathing expansion as well as maximal expansion. The reason the testing was done in sitting rather than standing as described in Bockenhauer et al. (2007), was that the other physical tests were assessed in sitting and the researcher wanted to investigate associations between these results in relation to the sitting position. Keeping the sitting position for all the upright tests also improved the ease of testing. The CTMT was adapted to include quiet breathing as this was needed to determine breathing pattern and was of interest to the researcher as an additional finding.

The participant was asked to sit facing forward while the researcher wrapped the tape measure around their thorax as high up into the axilla as was possible with the tape measure remaining in a horizontal line. The researcher stood to the left and back of the participant with the tape measure crossed over and held flat against the participant's back. The researcher recorded the measurement at each level with a voice recorder on her cell phone which was placed nearby. The first instruction to the participant was to breathe normally. The researcher did not restrict the breathing motion and once she was happy that the breathing was as normal, she recorded the expansion of three quiet breaths. The participant was then instructed to breathe in as deep as possible and exhale fully. This was repeated for three deep breaths and the researcher read out the circumference measurement at each inhale and exhale. The same procedure was repeated at the xiphoid level. Measurements were transcribed from the cell phone recording to the recording sheet after the assessment. There were no personal identifying features in the recording and after the measurements were written on the recording sheet, the recording was deleted. The difference between the circumference of an inspiration and expiration was calculated as the expansion at that level.

Breathing pattern was determined by comparing upper and lower thoracic expansion during quiet and deep breathing. If upper (axilla) expansion was greater than lower (xiphoid) expansion, this was noted as upper-costal breathing pattern. If lower (xiphoid) expansion was greater than upper (axilla) this was noted as costo-diaphragmatic breathing pattern. Due to the researcher performing the testing, she hoped to minimise bias by using expansion values to determine the breathing pattern rather than observation or palpation described in other literature.

3.5.2.3 Surface Electromyography (sEMG)

In preparation for measuring sEMG, the neck was cleaned with a damp towel to remove any cream or sweat that may interfere with conductivity. Probes were then placed on the left side of the neck for the sternal head of the sternocleidomastoid and the anterior scalene muscle and secured with Fixomull tape. Two round electrodes, 30 mm in diameter, were used and were placed 10 mm apart with the lower electrode in the lower third of the muscle. The reference electrode was placed on the left deltoid of the participant and the participant was asked to keep this arm relaxed.

To assess sEMG during quiet breathing, the participant was instructed to sit relaxed in the chair, to look forward and not to move the head or arms and not to speak. The EMG machine was programmed to measure muscle activity for two sets of 30 seconds (60 seconds in total). To assess sEMG during deep breathing, the participant was asked to take deep breathes, breathing in for four seconds breathing and out for six seconds. Two recordings were done of three breaths each. Muscle activity was measured during the inspiration phase only and the average of the two recordings was calculated as the sEMG reading for deep breathing. This test was done before the BHT measurement to minimise any sympathetic response that may be caused by the stress of breath-holding. It was also done before the CCFT to minimise fatigue or activation of the neck muscles that may occur during the CCFT.

3.5.2.4 Respiratory Rate

While the sEMG was measuring muscle activity for quiet breathing, the researcher was able to observe and record respiratory rate for one minute, using her cell phone to confirm the time. This was done by observation of the chest and abdomen while the participant was sitting.

3.5.2.5 Breath Hold Time (BHT)

While sitting, the participant was instructed to breathe in to prepare, and then breathe out to the point at which they would normally take another breath (functional residual volume). At this point the participant was required to hold their breath for as long as they could. The researcher sat in front of the participant so that she could observe any chest movement or inspiration during the test. The participant was allowed a practice measurement, however if they were happy with their time during this practice and the researcher was satisfied that it was done correctly, it could be used as one of the three recorded measurements. The participant and the researcher both used a phone stopwatch and the average of three measurements was recorded. In between each trial the participant was allowed a thirty-second rest period. If the researcher's recording differed from the participant's recording by more than one second, the measurement was repeated.

3.5.2.6 Cranio-Cervical Flexion Test (CCFT)

The CCFT was administered last. The participant was asked to lie on the treatment bed without a pillow under their head with their knees bent (in crook-lying). If there was no treatment bed the participant lay on a carpet or exercise mat on the floor. The researcher ensured that the head was in a neutral position. If the neck was in extension due to a kyphotic thoracic posture, a folded towel was placed under the participants head and neck to correct this position. The biofeedback cuff was placed under the participant's upper cervical spine and if the participant had a long neck, a pillowcase was placed under the lower cervical spine to prevent the cuff from sliding down. A pillow was placed on the participants abdomen and chest so that the participant could hold the biofeedback comfortably with both hands clasped and resting on the pillow. The cuff was inflated so that the pressure reading was 20 mmHg. The participant was then instructed to make a nodding action with their head and watch the needle on the biofeedback device. Once the participant and researcher were happy with the action required, the head position and cuff pressure were re-adjusted and the participant was asked to increase the pressure from 20 mmHg to 30 mmHg in increments of 2 mmHg by performing a head nod, holding each level for 10 seconds. The highest level the participant could reach was noted. At this level the participant was asked to perform as many 10-second holds as they could up to 10 times, with a brief rest period in between each hold. If the participant could compete 10 sets of 10-second holds at this level, this was recorded to be their level reached. If the participant could not complete the 10 sets, their level was recorded to be the level below. The participant's performance was rated as good, moderate or poor by the researcher. Performance was based on their ability to keep the needle steady and demonstrate minimal superficial muscle activity. This was done separately to the level recording to minimise possible bias from the researcher in determining the CCFT level.

3.6 Ethical considerations

Permission was obtained from the University of Witwatersrand Human Resource Ethics Committee (M190352) to conduct the study. No questionnaire or testing was done before a written consent form was signed. Before each participant was asked to sign the consent form, the study was explained in full as well as its importance and what was required of them. Participants could withdraw from the study at any point without repercussions. Participants were notified that should any test cause distress, a debriefing session would be organised, and appropriate referral recommended.

The consent form was kept separately to the completed data pack and recording sheet for confidentiality purposes. Each participant was identified by a unique coding number on the data pack and recording sheet. The name of the participants and their corresponding coded number were kept separately from the data pack. Only the researcher had access to the raw data and personal details of the participants. Any publishing of the results will contain anonymised data, without names of participants or personal information.

The participants were given feedback regarding their results. With the participant's permission, results were also discussed with the treating physiotherapist in order to influence treatment favourably. In this way the participants benefited from the assessment. The results will also be published for the benefit of other health professionals and their patients with neck pain.

3.7 Data analysis

Data analysis was done with the help of a biostatistician using SAS (Institute Inc, Carey, NC, USA) release 9.4.

A two-sample t test was used to analyse the differences between the neck pain and control groups for each variable. Fisher's exact test was used to evaluate the difference in variables between categories or smaller groups, which gave a more precise outcome. Spearman correlation coefficients were used to evaluate correlations for all statistics relating to questionnaire scores and parametric data. Pearson correlation coefficients were used to evaluate correlations between variables including sEMG readings. The statistical tests that were used assumed normal distribution of the data and homogenous variance in each group based on the sample size being over 30 participants (Krithikadatta, 2014). An alpha level of 0.05 is commonly used to determine significance. However, recent literature suggests that such a specific cut-off may detract from the interpretation of the results (Wasserstein et al., 2019). Therefore, the p-values are provided for the reader's interpretation and significance is mentioned with caution. Correlation r values were interpreted as follows: r value of 0.00 - 0.25 indicates little or no relationship, 0.26 - 0.50 fair relationship, 0.51 - 0.75 moderate to good relationship, and more than 0.75 a good to excellent relationship (Portney and Watkins, 2009). The statistical tests that were used during the data analysis are summarised in Table 3-6 below.

Table 3-6 Summary of statistical tests used

Objective	Description	Statistical test
1	Differences in CCFT level and performance rating between groups	Fisher's exact test
2	Differences in measures of respiration and dysfunctional breathing between groups	Two-sample t test
	Differences in respiratory rate, NQ, SEBQ and BHT between groups in categories	Fisher's exact test
3	Differences in muscle activity between participants with and without neck pain	Two-sample t test
4	Differences in perceived stress between groups	Two-sample t test
5	Correlation of neck pain, neck disability and CCFT level with breathing outcomes	Spearman correlation coefficient
6	Correlation of muscle activity with neck pain and neck disability	Pearson correlation coefficient
7	Correlation of muscle activity with thoracic expansion	Pearson correlation coefficient
8	Differences in muscle activity between breathing patterns	Two-sample t test
9	Correlation of perceived stress with neck pain and disability in the neck pain group as well as respiratory rate, NQ, SEBQ and BHT in both groups	Spearman correlation coefficient
*	Differences in age between groups	Two-sample t test
*	Differences in BMI between groups	Two-sample t test

*	Differences in asthma or chest problems, use of anxiety or depression medication, or sinus or allergy problems between groups	Fisher's exact test
*	Differences in the number of times the participant exercised in a week and the type of exercise they did	Fisher's exact test
*	Differences in the number of hours spent at the computer per day between groups	Fisher's exact test
*****	Correlation of pain and disability with CCFT performance rating	Fisher's exact test

*****These tests are not associated with the study objectives but form part of the results

3.8 Conclusion of the methodology

This cross-sectional analytical study recruited a sample of 49 participants with neck pain and 49 matched controls. The participants were volunteers who met the inclusion and exclusion criteria for the study and were sourced from a private practice in Johannesburg, South Africa as well as from the general public. The assessment tools that were used to evaluate neck pain and dysfunction, as well as respiration and dysfunctional breathing included questionnaires (NDI, NQ, SEBQ, PSS and the researcher's questionnaire which included the NRS), and physical tests (CTMT, sEMG, respiratory rate, BHT and CCFT). Explanation was given regarding the clinical use and interpretation of these tools, as well as the procedure of the data collection during the current study. The way in which ethical considerations were observed and approved, and the statistical tests used for data analysis, have been discussed.

4 RESULTS

This chapter presents and summarises the results of the study. The first section summarises participant demographics as well as reported pain intensity and neck disability ratings in the neck pain group. Sections 4.2 to 4.5 present the differences of CCFT, breathing outcomes, muscle activity and perceived stress between the neck pain and control groups. This is followed by results presenting the correlation between variables relating to neck pain and dysfunction, breathing outcomes and perceived stress. Lastly, results regarding confounding variables are presented. Statistical tests used and the interpretation of p-values and r-values are outlined in section 3.7.

4.1 Participants

4.1.1 Demographics

The sample consisted of 98 participants: 49 participants with neck pain and 49 age (±5 years) and sex matched controls. There was no difference in sex between the neck pain and control groups, and age was similar. Sex and age differences are summarised in Table 4-1 and Table 4-2 respectively.

Table 4-1 Summary of participant sex

	Neck pain (n=49)	Control (n=49)
Male (n (%))	11 (22.5)	11 (22.5)
Female (n (%))	38 (77.5)	38 (77.5)

Table 4-2 Summary of participant age

	Neck pain (n=49)		Control (n=49)		Two-sample t test
	Mean (SD)	Range	Mean (SD)	Range	p
Age (y)	36.5 (±11.49)	23 - 60	36.2 (±11.92)	21 - 60	0.918

SD – standard deviation; y - years

4.1.2 Pain intensity and neck disability of participants in the neck pain group

The pain intensity ratings (NRS) and NDI scores of participants with neck pain are summarised in Table 4-3. The average pain intensity that the participants were experiencing at the time of assessment rated on the NRS out of 10 was 4.37 indicating mild pain (Boonstra et al., 2016). The average sum of current, best and worst pain in the last 24 hours was 12.5 and, when averaged out of 10, also fell in the category for mild pain. According to the pain categories of mild, moderate and severe, there were 31 participants (63%) who reported mild pain, 16 (33%) moderate pain and 2 (4%) reported severe pain (Figure 4-1).

The mean score on the NDI for neck disability was 10.98 (Table 4-3) indicating mild disability (Vernon, 2008). When disability was divided into categories, 3 (6%) participants had no disability, 36 (74%) had scores indicating mild disability and 10 (20%) had moderate disability (Figure 4-2).

Table 4-3 Summary of pain and disability of participants in the neck pain group

	Mean (SD)	Range
Current pain (/10)	4.37 (±2.06)	0-8
Sum 24hr pain (/30)	12.50 (±5.60)	1-24
NDI	10.98 (±5.19)	3-23

hr – hour; NDI – Neck Disability Index; SD – standard deviation

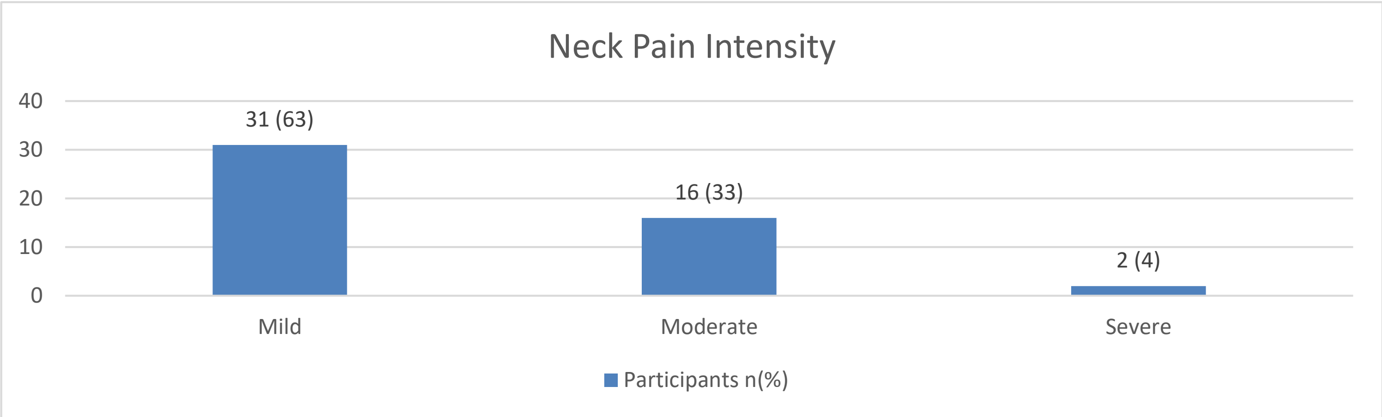

Figure 4-1 Participants of the neck pain group in categories of mild, moderate and severe neck pain

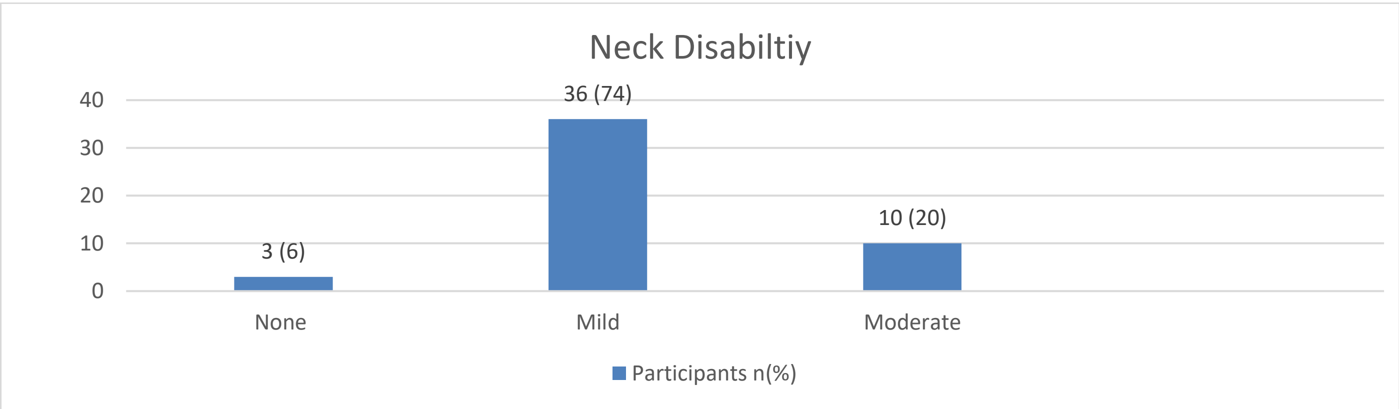

Figure 4-2 Participants of the neck pain group in categories of none, mild and moderate neck disability

4.2 Deep neck flexor strength

Deep neck flexor strength was assessed using the CCFT. The CCFT level was determined by the pressure at which the participant could hold 10 sets of 10-second holds between 20 mmHg and 30 mmHg in intervals of 2 mmHg. The control group completed higher levels of the CCFT than the neck pain group (p=0.0029), with more participants in the control group able to hold the highest level (30 mmHg) compared to those in the neck pain group (Table 4-4).

Table 4-4 Number of participants able to hold each level of the Cranio-Cervical Flexion Test (CCFT)

	Neck pain (n=49)	Control (n=49)	Fisher's exact test p
24 mmHg	2	1	0.0029
26 mmHg	0	2	
28 mmHg	8	0	
30 mmHg	39	46	

The CCFT performance was rated as good, moderate or poor for each participant by the researcher. This was based on the ability of the participant to hold the needle steady and the recruitment of superficial neck muscles. The control group had significantly better performance rating than the neck pain group (p<0.0001) with almost 45% of the neck pain group being rated as having poor performance (Table 4-5).

Table 4-5 Number of participants scoring in categories of good, moderate and poor in the Cranio-Cervical Flexion Test (CCFT)

	Neck pain (n=49)	Control (n=49)	Fisher's exact test p
Good (n (%))	10 (20.41)	29 (59.18)	< 0.0001
Moderate (n (%))	17 (34.69)	15 (30.61)	
Poor (n (%))	22 (44.90)	5 (10.20)	

4.3 Breathing outcomes

Table 4-6 summarises the differences in breathing outcomes between the neck pain and control groups. The neck pain group and controls were similar in respiratory rate, CTMT, breathing patterns and BHT. Participants in the neck pain group reported higher scores in both the NQ (p=0.0005) and SEBQ (p=0.0001) than participants in the control group.

Table 4-6 Differences in breathing outcomes between participants with and without neck pain

	Neck pain (n=49)		Control (n=49)		Two-sample t test
	Mean (SD)	Range	Mean (SD)	Range	p
Respiratory rate (bpm)	14.99 (±3.58)	9-24	14.70 (±3.05)	7-20	0.6715
Quiet breathing: axilla (cm)	00.74 (±0.42)	0.20-1.80	00.72 (±0.33)	0.10-1.57	0.8073
Quiet breathing: xiphoid (cm)	01.06 (±0.69)	0.17-3.03	01.03 (±0.67)	0.27- 3.47	0.8720
Deep breathing: axilla (cm)	03.29 (±1.49)	0.90-7.70	03.73 (±1.39)	0.53- 6.86	0.1324
Quiet breathing: xiphoid (cm)	4.51 (±2.27)	0.56-12.33	04.93 (±1.86)	0.53- 8.73	0.3166
NQ	17.83 (±10.25)	0-42	11.18 (±7.51)	0-33	0.0005
SEBQ	17.38 (±12.45)	0-51	08.90 (±7.19)	0-28	0.0001
BHT (s)	26.87 (±9.24)	11.90-53.88	30.33 (±10.89)	14.33-70.56	0.0932

BHT - Breath Hold Time; bpm - breaths per minute; NQ - Nijmegen Questionnaire; SEBQ - Self-Evaluation of Breathing Questionnaire

Table 4-7 summarises the breathing patterns based on the ratios of thoracic expansion at axilla and xiphoid levels. The number of participants with each breathing pattern was similar in the neck pain and control groups for quiet and deep breathing.

Table 4-7 Summary of breathing patterns for quiet and deep breathing

	Quiet Breathing (n=98)		Deep Breathing (n=98)	
	Neck pain (n=49)	Control (n=49)	Neck pain (n=49)	Control (n=49)
Upper-costal n (%)	13 (26.53)	13 (26.53)	8 (16.33)	6 (12.25)
Costo-diaphragmatic n (%)	35 (71.43)	35 (71.43)	41 (83.67)	42 (85.71)
Mixed n (%)	1 (2.04)	1 (2.04)	0 (0.00)	1 (2.04)

A normal respiratory rate in adults has been reported to be between 12 and 16 (Pryor and Prasad, 2008) or between 10 and 14 (Bradley, 2014). Bradypnea is when the respiratory rate is below 10 breaths per minute and tachypnoea is when the respiratory rate is greater than 20 breaths per minute (Pryor and Prasad, 2008). Respiratory rate was similar between the groups when divided into categories (p=0.71) and is summarised in Table 4-8.

Table 4-8 Summary of respiratory rate in categories

Respiratory rate (bpm)	Neck pain (n=49) n (%)	Control (n=49) n (%)	Fisher's exact test p
<10	1 (2)	1 (2)	
10-12	7 (14.29)	5 (10.2)	
12-16	24 (48.98)	31 (63.27)	0.710
17-20	13 (26.53)	12 (24.49)	
>20	4 (8.16)	0 (0)	

bpm - breaths per minute

The NQ and SEBQ questionnaires are commonly used in the diagnosis of dysfunctional breathing. A score of above 22 on the NQ and above 10 on the SEBQ is considered positive for dysfunctional breathing. There were more people in the neck pain group diagnosed with dysfunctional breathing using the NQ (p=0.0093) and the SEBQ (p=0.0022) than in the control group. The results of the NQ and SEBQ in categories of dysfunctional breathing and normal breathing are summarised in Tables 4-9 and 4-10 respectively.

Table 4-9 Summary of participants with normal and dysfunctional breathing according to the Nijmegen Questionnaire (NQ)

	Neck pain (n=49) n (%)	Control (n=49) n (%)	Fisher's exact test p
Normal breathing (< 23)	34 (69.39)	45 (91.84)	0.009
Dysfunctional breathing (≥ 23)	15 (30.61)	4 (8.16)	

Table 4-10 Summary of participants with normal and dysfunctional breathing according to the Self-Evaluation of Breathing Questionnaire (SEBQ)

	Neck pain (n=49) n (%)	Control (n=49) n (%)	Fisher's exact test p
Normal breathing (< 11)	18 (36.73)	34 (69.39)	0.002
Dysfunctional breathing (≥ 11)	31 (63.27)	15 (30.61)	

A BHT of less than 20 seconds may be considered positive for dysfunctional breathing (Warburton and Jack, 2006). Breath Hold Time (BHT) was similar in both the groups using these categories (p=0.237) and is summarised in Table 4-11. It may be of some clinical relevance that there were more participants in the neck pain group who had a BHT of less than 20 seconds and more participants in the control group who had a BHT greater than 29 seconds (Table 4-11).

Table 4-11 Summary of Breath Hold Time (BHT) in categories

Breath Hold Time (s)	Neck pain (n=49) n (%)	Control (n=49) n (%)	Fisher's exact test p
<20	11 (22.45)	5 (10.20)	0.237
20-29	21 (42.86)	22 (44.9)	
>29	17 (34.69)	22 (44.9)	

BHT – Breath Hold Time

4.4 Muscle activity

The mean sEMG readings for scalene and sternocleidomastoid muscles were similar in both the neck pain and control groups for quiet and deep breathing. Muscle activity during quiet breathing is summarised in Table 4-12 and muscle activity during deep breathing is summarised in Table 4-13.

Table 4-12 Summary of sEMG during quiet breathing for sternocleidomastoid and scalene muscles

	Neck pain (n=49)		Control (n=49)		Two-sample t test
	Mean (SD)	Range	Mean (SD)	Range	p
SCM (μV)	28.45 (±46.16)	1.40-182.0	33.17 (±44.78)	1.60-195	0.608
Scalene (μV)	24.15 (±47.60)	1.8-287	25.20 (±34.09)	1.7-141	0.901

SCM – sternocleidomastoid; μV – microvolts

Table 4-13 Summary of sEMG during deep breathing for sternocleidomastoid and scalene muscles

	Neck pain (n=49)		Control (n=49)		Two-sample t test
	Mean (SD)	Range	Mean (SD)	Range	p
SCM (µV)	65.48 (±62.73)	3.30-270	75.48 (±83.22)	2.35-302	0.503
Scalene (µV)	69.73 (±65.04)	7.15-265.5	69.33 (±78.63)	3.6-354.5	0.978

SCM – sternocleidomastoid; µV – microvolts

4.5 Perceived stress

The PSS gives an indication of perceived distress and perceived coping. The PSS mean scores were similar in participants with and without neck pain (p=0.464) and are summarised in Table 4-14.

Table 4-14 Summary of Perceived Stress Scale (PSS)

Neck pain (n=49)		Control (n=49)		Two-sample t test
Mean (SD)	Range	Mean (SD)	Range	p
17.16 (±7.38)	2-32	16.04 (±7.72)	1-31	0.464

4.6 The association of neck pain and neck disability with measures of breathing

The breathing outcomes used in this study can be analysed in two categories: measures of respiration (respiratory rate, CTMT and breathing pattern) and measures of dysfunctional breathing (NQ, SEBQ and BHT). Table 4-15 summarises the correlation of neck pain and neck disability with respiratory rate and thoracic expansion. Respiratory rate correlated fairly with neck disability (r=0.441; p=0.002) but not with current pain (r=0.098; p=0.505) or sum of best, worst and current pain (r-0.131; p=0.370). There was little to no correlation of neck pain intensity or neck disability with thoracic expansion during quiet breathing. There was little to no correlation between neck pain intensity or neck disability and thoracic expansion during deep breathing at the axilla level. There was a fair correlation between neck disability (but not pain intensity) and thoracic expansion during deep breathing at the xiphoid level (r=-0.286; p=0.047).

Table 4-15 Correlation of neck pain and disability with respiratory rate and thoracic expansion

Spearman correlation coefficients		Neck pain group (n=49)					
		Current pain (NRS)		Sum of 24hr pain		NDI	
		r	P	r	p	r	p
Respiratory rate		0.098	0.505	0.131	0.370	0.441	0.002
Quiet breathing	Axilla	-0.206	0.156	-0.187	0.220	-0.237	0.101
	Xiphoid	-0.025	0.863	-0.015	0.918	-0.247	0.088
Deep breathing	Axilla	-0.244	0.091	-0.260	0.071	-0.226	0.119
	Xiphoid	-0.077	0.600	-0.128	0.382	-0.286	0.047

NDI – Neck Disability Index; NRS – Numeric Rating Scale

Table 4-16 summarises the association of dysfunctional breathing assessment measures with neck pain and disability. There was a moderate correlation between the NQ and NDI (r=0.501; p=0.0002). The SEBQ correlated fairly with current pain (r=0.291; p=0.043) and the sum of best, worst and current pain (r=0.293; p=0.041), and correlated moderately with neck disability (r=0.563; p<0.0001). BHT had little to no correlation with neck pain intensity or neck disability.

Table 4-16 Correlation of neck pain and disability with measures of dysfunctional breathing

Spearman correlation coefficients	Neck pain group (n=49)					
	Current pain (NRS)		Sum of 24hr pain		NDI	
	r	P	r	p	r	p
NQ	0.205	0.158	0.216	0.135	0.501	0.0002
SEBQ	0.291	0.043	0.293	0.041	0.563	< 0.0001
BHT	-0.063	0.666	-0.115	0.432	-0.151	0.230

BHT - Breath Hold Time; NRS – Numeric Rating Scale; NDI – Neck Disability Index; NQ - Nijmegen Questionnaire; SEBQ - Self-Evaluation of Breathing Questionnaire

The level reached performing the CCFT did not correlate with any measures of respiration or dysfunctional breathing and is summarised in Table 4-17.

Table 4-17 Correlation of Cranio-Cervical Flexion Test (CCFT) level with measures of breathing

Spearman correlation coefficients		Participants with and without neck pain (n=98)	
		r	p
Respiratory rate		-0.207	0.041
Quiet breathing	Axilla	0.059	0.567
	Xiphoid	-0.164	0.107
Deep breathing	Axilla	0.003	0.980
	Xiphoid	0.064	0.530
NQ		-0.065	0.522
SEBQ		-0.054	0.595
BHT		0.240	0.017

CCFT – Cranio-Cervical Flexion Test; NQ – Nijmegen Questionnaire; SEBQ – Self-Evaluation of Breathing Questionnaire

4.7 The association of neck pain and neck disability with muscle activity

There was little to no correlation between neck pain and sEMG readings for sternocleidomastoid or scalene muscles during quiet and deep breathing. Likewise, there was little to no correlation between neck disability and sEMG readings for sternocleidomastoid or scalene muscles during quiet and deep breathing. Correlations of neck pain and disability with sEMG are summarised in Table 4-18.

Table 4-18 Correlation of muscle activity during quiet and deep breathing with neck pain and disability

Pearson correlation coefficient	Quiet breathing (n=49)				Deep breathing (n=49)			
	Current pain (NRS)		NDI score		Current pain (NRS)		NDI score	
	r	p	R	p	r	p	r	p
SCM	0.134	0.359	0.002	0.987	0.201	0.167	0.001	0.997
Scalene	-0.017	0.910	-0.055	0.708	0.190	0.192	0.125	0.394

NRS - Numeric Rating Scale; NDI - Neck Disability Index; SCM - sternocleidomastoid

4.8 The association of thoracic expansion with muscle activity

Table 4-19 summarises the correlation between sEMG and CTMT for quiet and deep breathing at axilla (upper thoracic) and xiphoid (lower thoracic) levels. Correlation was investigated between quiet breathing sEMG and quiet breathing expansion, and between deep breathing sEMG and maximum expansion. There was little to no correlation between sEMG and CTMT during quiet or deep breathing.

Table 4-19 Correlation of muscle activity during quiet and deep breathing with thoracic expansion at axilla and xiphoid levels

Pearson correlation coefficient	Quiet breathing (n=98)				Deep breathing (n=98)			
	Axilla		Xiphoid		Axilla		Xiphoid	
	r	p	r	p	r	p	r	p
SCM	0.057	0.576	-0.099	0.333	0.035	0.734	0.051	0.619
Scalene	0.065	0.528	-0.050	0.623	0.083	0.419	0.099	0.334

SCM – sternocleidomastoid

4.9 Differences in muscle activity between breathing patterns

Breathing pattern was determined by the ratio of axilla expansion to xiphoid expansion for quiet and deep breathing. Table 4-20 and Table 4-21 summarise the muscle activity of the sternocleidomastoid and scalene muscles for upper-costal and costo-diaphragmatic breathing patterns. Muscle activity during rest was analysed in relation to quiet breathing patterns and muscle activity during deep breathing was analysed in relation to deep breathing patterns. During quiet breathing, sEMG readings of sternocleidomastoid and scalene muscles were similar between breathing patterns for participants with and without neck pain (Table 4-20). During deep breathing, the scalene sEMG measurement was greater for participants in the neck pain group who breathed with a costo-diaphragmatic breathing pattern compared to those who breathed with an upper-costal breathing pattern ($p=0.033$). This difference was not noted in the control group (Table 4-21).

Table 4-20 Summary of surface electromyography (sEMG) and breathing patterns during quiet breathing

	Neck pain (n=49)			Control (n=49)		
	Upper-costal	Costo-diaphragmatic	Two-sample t test	Upper-costal	Costo-diaphragmatic	Two-sample t test
	Mean (SD)	Mean (SD)	p	Mean (SD)	Mean (SD)	p
SCM (μV)	30.93 (±46.40)	23.14 (±39.03)	0.562	44.08 (±51.69)	30.00 (±42.47)	0.341
Scalene (μV)	11.17 (±15.30)	76.22 (±73.70)	0.094	37.06 (±45.33)	21.43 (±28.86)	0.264

SCM – sternocleidomastoid; sEMG – surface electromyography; uV – microvolts

Table 4-21 Summary of surface electromyography (sEMG) and breathing patterns during deep breathing

	Neck pain (n=49)			Control (n=49)		
	Upper-costal	Costo-diaphragmatic	Two-sample t test	Upper-costal	Costo-diaphragmatic	Two-sample t test
	Mean (SD)	Mean (SD)	p	Mean (SD)	Mean (SD)	p
SCM (μV)	31.10 (±32.08)	72.19 (±65.26)	0.090	56.58 (±81.60)	78.14 (±85.07)	0.563
Scalene (μV)	43.84 (±24.67)	74.78 (±69.35)	0.033	52.33 (±54.12)	72.26 (±82.58)	0.571

SCM – sternocleidomastoid; sEMG – surface electromyography; SD – standard deviation; uV – microvolts

4.10 The association of perceived stress with neck pain, neck disability and breathing outcomes

Table 4-22 summarises the correlation of neck pain and neck disability with perceived stress in participants with neck pain. There was little to no association between the PSS and neck pain (NRS). There was a weak correlation between the PSS and NDI (r=0.259, p=0.073).

Table 4-22 Correlation of perceived stress with neck pain and disability in the neck pain group

Spearman correlation coefficient	Neck pain group (n=49)	
	r	p
Current pain (NRS /10)	0.120	0.411
Sum 24hr pain (NRS /30)	0.104	0.476
NDI	0.259	0.073

NRS - Numeric Rating Scale; NDI - Neck Disability Index

Table 4-23 summarises the correlation of perceived stress with respiratory rate and measures of dysfunctional breathing (NQ, SEBQ, BHT). There was a moderate to strong correlation between the PSS and the NQ ($r=0.535$; $p<0.0001$; $r=0.646$; $p<0.0001$) and SEBQ ($r=0.548$; $p<0.0001$; $r=0.566$; $p<0.0001$) in both the neck pain and control groups. No correlation was found between the PSS and respiratory rate or BHT in either group.

Table 4-23 Correlation of perceived stress (PSS) with respiratory rate and measures of dysfunctional breathing

Spearman correlation coefficient	Neck pain (n=49)		Control (n=49)	
	r	p	r	p
Respiratory rate	0.076	0.605	0.001	0.968
NQ	0.535	< 0.0001	0.646	< 0.0001
SEBQ	0.548	< 0.0001	0.566	< 0.0001
BHT	-0.202	0.165	-0.016	0.915

BHT - Breath Hold Time; NQ - Nijmegen Questionnaire; SEBQ – Self-Evaluation of Breathing Questionnaire

4.11 Association of deep neck flexor control with neck pain and neck disability in the neck pain group

Performance of the CCFT was rated by the researcher as good, moderate or poor according to the steadiness of the needle and the recruitment of superficial muscles. CCFT performance was not associated with neck pain (p=0.976) or disability scores (p=0.240). Table 4-24 and 4-25 summarise the CCFT performance in relation to neck pain and disability.

Table 4-24 Summary of Cranio-Cervical Flexion Test (CCFT) performance rating with current pain in categories of mild, moderate and severe pain

	Neck pain group (n=49)			Fisher's exact test p
	Good n (%)	Moderate n (%)	Poor n (%)	
Mild (0-5)	7 (70.00)	11 (64.71)	13 (59.09)	0.976
Moderate (6-7)	3 (30.00)	5 (29.41)	8 (36.36)	
Severe (8-10)	0 (0.00)	1 (5.88)	1 (4.55)	

Table 4-25 Summary of Cranio-Cervical Flexion Test (CCFT) performance rating with neck disability in categories of none, mild and moderate disability

	Neck pain group (n=49)			Fisher's exact test p
	Good n (%)	Moderate n (%)	Poor n (%)	
None (0-4)	1 (10.00)	0 (0.00)	2 (9.09)	0.240
Mild (5-14)	9 (90.00)	12 (70.59)	15 (68.18)	
Moderate (15-24)	0 (0.00)	5 (29.41)	5 (22.73)	

4.12 Additional confounding variables

Background information was gathered with "yes/no" questions in the researcher's questionnaire regarding asthma or chest problems, if the participant was currently using medication for anxiety or depression, and if they frequently struggled with nasal congestion, sinus problems, rhinitis or allergies affecting nasal passages (Table 4-26). The number of participants with asthma or chest problems was similar between the neck pain and control groups (p=0.524). There were more than double the participants taking medication for anxiety or depression in the neck pain group compared to the control group (11 participants in the neck pain group verses 5 participants in the control group). However, this difference was not statistically significant (p=0.171). More participants with neck pain reported allergies and nasal congestion than participants in the control group (p=0.042).

Table 4-26 Additional information regarding possible confounding factors

	Neck pain (n=49) n (%)	Control (n=49) n (%)	Fisher's exact test p
Asthma or frequent chest problems	4 (8.16)	7 (14.29)	0.524
Anxiety or depression medication	11 (22.45)	5 (10.20)	0.171
Nasal and sinus problems or frequent allergies	28 (57.14)	17 (34.69)	0.042

The overall exercise frequency per week was slightly more in the control group compared to the neck pain group (p=0.092). When analysis was done for each category, the number of participants who exercised more than three times a week was significantly greater in the control group compared to the neck pain group (p=0.041). Exercise frequency per week is summarised in Table 4-27.

Table 4-27 Exercise frequency per week

	Neck pain (n=49)	Control (n=49)	Fisher's exact test	
	n (%)	n (%)	p	p
Never	9 (18.37)	5 (10.20)	0.387	
1 – 3 times a week	24 (48.98)	17 (34.69)	0.219	0.092
> 3 times	16 (32.65)	27 (55.10)	0.041	

The types of exercise that participants undertook were similar between the groups and are summarised in Table 4-28. More participants in the neck pain group cycled (18 participants) compared to the control group (10 participants) which may be of some clinical relevance.

Table 4-28 Type of exercise

	Neck pain (n=49) n (%)	Control (n=49) n (%)	Fisher's exact test p
Cycling	18 (36.73)	10 (20.41)	0.117
Running	24 (48.98)	25 (51.02)	1.000
Strength	20 (40.82)	20 (40.82)	1.000
Pilates/yoga	11 (22.45)	13 (26.53)	0.815

The number of hours spent at a computer was similar in both the neck pain and control group (p=0.564) and is summarised in Table 4-29.

Table 4-29 Hours per day spent at a computer

	Neck pain (n=49) n (%)	Control (n=49) n (%)	Fisher's exact test p
Less than 3 hours	15 (30.61)	9 (18.37)	0.564
3-6 hours	7 (14.29)	9 (18.37)	
6-8 hours	16 (32.65)	18 (36.73)	
More than 8 hours	11 (22.45)	13 (26.53)	

Body mass index (BMI) was similar in both groups and is summarised in Table 4-30.

Table 4-30 Body mass index (BMI)

Neck pain (n=49)		Control (n=49)		Two-sample t test
Mean (SD)	Range	Mean (SD)	Range	p
24.51 (±4.10)	17.30 - 36.33	24.15 (±3.64)	18.29 - 34.77	0.639

4.13 Conclusion of the results

In summary, the neck pain and control groups had the same number of females and males in each group. Age was similar in each group and ranged between 21 and 60 years. Participants with neck pain generally reported mild pain intensity and mild neck disability. Participants with neck pain performed worse in the CCFT than those without. Respiratory rate, thoracic expansion, breathing pattern, BHT and PSS were similar in participants with or without neck pain. Participants with neck pain scored higher on the NQ and SEBQ compared to the control group. There were also significantly more people with neck pain diagnosed with dysfunctional breathing using the NQ and SEBQ than in the control group. Muscle activity was similar in the neck pain and control groups for sternocleidomastoid and scalene muscles, during quiet and deep breathing.

A fair correlation was found between respiratory rate and the NDI. The SEBQ correlated fairly with neck pain and both the NQ and SEBQ correlated moderately to strongly with the NDI. The PSS correlated moderately to strongly with the NQ and SEBQ but did not correlate with pain, NDI, BHT or respiratory rate. There was little to no correlation between sEMG and pain, disability or thoracic expansion. No difference was found in muscle activity between breathing patterns during quiet breathing; however, the muscle activity of the scalene muscle was greater during deep breathing for participants in the neck pain group using costo-diaphragmatic breathing pattern compared to those with an upper-costal breathing pattern.

Statistical analysis regarding confounding variables revealed that participants in the control group exercised more frequently than participants with neck pain, and that participants with neck pain were more likely to experience allergies, sinus or nasal problems than participants in the control group. Chest problems including asthma, use of anxiety and depression medication, type of exercise, hours per day spent at a computer and BMI were similar between the groups.

To conclude, the main findings of this research were that participants with neck pain scored higher on the NQ and SEBQ than participants without neck pain, and that the NQ and SEBQ scores were positively associated with neck disability and perceived stress. Muscle activity did not appear to play a major role in neck pain and dysfunction or breathing measures. These results will be discussed, with reference to the literature, in the next chapter.

5 DISCUSSION

This chapter discusses all the relevant results of this study in relation to the literature and will give possible reasons for these results in the light of what other studies have reported. Section 5.1 will discuss the demographics of the participants in both groups, as well as reported pain and disability in the neck pain group. Section 5.2 will discuss deep neck flexor strength, 5.3 breathing outcomes, 5.4 muscle activity, 5.5 perceived stress and 5.6 confounding variables. In each section, differences in outcomes between the groups as well as correlations will be discussed. Relevant r values and p values are given where necessary to aid in the interpretation of results.

5.1 Participant demographics and reported neck dysfunction

In this study, matching of sex ensured that there were the same number of males and females in the control group and the neck pain group. Overall, most participants were female. Neck pain is more prevalent in females than males (Fejer et al., 2006; Hoy et al., 2010; Cohen, 2015; Hurwitz et al., 2018a), and being female has been reported to be a strong risk factor for new onset of neck pain (Blanpied et al., 2017). Females experiencing neck pain are also more likely to develop persistent neck pain than males (Cohen, 2015). The differences in pain experience between sexes may be due to differences in sex hormones (Maurer et al., 2016; Sorge and Totsch, 2017). The way in which sex hormones may contribute towards neck pain is beyond the scope of this dissertation.

Blanpied et al. (2017) reported an increase in risk for developing neck pain over the age of 40, with the highest prevalence of neck pain being in women during the fifth decade. Hoy et al. (2010) reports that the peak prevalence of neck pain is in the age group 35 to 49 years, while Hoy et al. (2014) reports peak prevalence within a narrower margin of 40 to 45 years of age. The average age of the participants in the current study (around 36 years) was younger than what has previously been reported. This may be because convenience sampling allowed the researcher to invite friends or colleagues to participate. Several participants with neck pain were not seeing a health professional at the time of testing, therefore the population might have differed from other studies that gathered information from healthcare facilities.

The mild pain reported by most of the participants may again be due to convenience sampling which allowed the researcher to recruit people from the general public not attending a healthcare facility.

Kato et al. (2012) reported that a score of 15 or more on the NDI generally indicated neck disability that would limit activity enough to cause a person to seek healthcare. In the current study, only 20% of the participants with neck pain had a score of 15 and above. Therefore, most participants in the current had few activity-limitations caused by neck pain, even if they were seeing a physiotherapist for this pain.

5.2 Deep neck flexor strength

The results of this study that the neck pain group completed a lower level on the CCFT (p=0.0029), and demonstrated poorer performance (p<0.0001) than the control group, agrees with other studies that report weakness of the deep neck flexors measured with the CCFT in people with neck pain, compared to those without neck pain (Chiu et al., 2005; Jull et al., 2008). However, Hudswell et al. (2005) did not find significantly reduced CCFT levels in people with neck pain. Instead, they reported a correlation of CCFT with neck pain intensity and disability.

In the current study, the CCFT level was recorded as the level the participants could repeat 10 sets of 10-second holds regardless of the quality of movement or contraction. Performance was rated separately as good, moderate or poor by the researcher based on needle steadiness and activation of the superficial muscles. The quality of contraction was therefore analysed separately from the level as performance in an attempt to minimise bias. This performance rating did not correlate with neck pain or disability, which may be due to the mild pain and disability scores in the neck pain group, or due to a difference in assessment methods. In the previous studies, the CCFT level was determined in relation to the number of steady holds at a pressure level as well as recruitment of superficial muscles (Chiu et al., 2005; Hudswell et al., 2005; Jull et al., 2008).

5.3 Breathing outcomes

5.3.1 Respiratory rate

Respiratory rate did not seem to be influenced in this study by pain which is contrary to what was expected as acute pain has been reported to cause an increase in respiratory rate (Wilhelm et al., 2001). The reason for these results may be because most of the neck pain group had mild neck pain, or it may have been due to the limited ability of the testing to determine other respiratory irregularities.

Hyperventilation, breath-holding, as well as deep slow breathing all have pain-modulating effects to an acute pain stimulus (Terekhin and Forster, 2006; Zautra et al., 2010; Busch et al., 2012; Reyes del Paso et al., 2015). Therefore, respiratory rate alone may not be sufficient to determine respiratory responses to pain. There were only four participants in the current study with a respiratory rate of above 20 and all four of these participants had neck pain. Therefore, in some cases pain may contribute to an increase in respiratory rate. However, the remaining participants with neck pain and normal respiratory rates may have demonstrated other respiratory adaptions undetected by respiratory rate observation, or had pain too mild to show respiratory changes. Respiratory changes in response to pain may vary and may be dependent not only on pain but the emotional response to pain.

The positive fair association between respiratory rate and neck disability and not pain in the neck pain group (r=0.44, p=0.002) indicates the link between respiration and psychological factors associated with disability.

Negative thoughts and emotions may influence respiratory rate (Wilhelm et al., 2001; Chenivesse et al., 2014), and psychosocial factors are strongly linked to disability related to the neck (Linton, 2000; Blozik et al., 2009). In this study, however, respiratory rate was not correlated with the PSS (see section 5.5), indicating that perhaps this trend was related to psychological factors surrounding the activity-limitations associated with the NDI and not general distress or coping as determined by the PSS. Although the NDI scores were mild and revealed minimal to no activity restriction, some limitation with regard to activity may still be present with mild disability.

5.3.2 Thoracic expansion

Thoracic expansion for quiet and deep breathing did not seem to be influenced by the presence of neck pain. This is contrary to findings that thoracic expansion during deep breathing, especially lower thoracic, is reduced in people with neck pain (Halim et al., 2016). Thoracic expansion may be an indication of respiratory function and strength (de Cordoba Lanza et al., 2013; Debouche et al., 2016). Previous literature reports reduced respiratory function and respiratory strength in people with neck pain (Kapreli et al., 2009; Dimitriadis et al., 2014; Wirth et al., 2014; López-de-Uralde-Villanueva et al., 2018). The reason why the current study did not find any significant difference in thoracic expansion between the neck pain group and controls may have been that most of the participants in the neck pain group had mild pain and mild neck disability. This is in agreement with another study that reported reduced respiratory strength compared to controls only in participants with moderate to severe neck disability (López-de-Uralde-Villanueva et al., 2018).

The method of assessment for thoracic expansion also differed in the current study compared to previous studies which would have influenced the results. Previous studies measured thoracic expansion in standing (de Cordoba Lanza et al., 2013; Debouche et al., 2016; Halim et al., 2016), whereas the present study measured thoracic expansion while sitting. In standing, the diaphragm is required to function in inspiration as well as being a postural muscle (Hodges and Gandevia, 2000), and therefore weakness may be more apparent. The sitting posture of the participants was not corrected; therefore, the researcher suggests that varied thoracic postures could have influenced the thoracic expansion.

Previous literature that investigated thoracic expansion in relation to neck pain did not analyse associations between expansion and pain or disability (Halim et al., 2016). Therefore, it is difficult to analyse the current results in relation to other literature. However, as CTMT may give an indication of respiratory function and strength (de Cordoba Lanza et al., 2013; Debouche et al., 2016), relevant literature regarding respiratory function and respiratory strength may help in the interpretation of the current study's findings. Respiratory function (VC and MVV) is reported to be associated with "usual" pain intensity (Dimitriadis et al., 2014) and respiratory strength has been reported to be correlated to neck disability (Wirth et al., 2014). Again, the lack of association found in this study is likely due to the mild pain and disability in the neck pain group.

5.3.3 Breathing pattern

The ratio between upper and lower thoracic expansion was used to determine breathing pattern. The presence of neck pain did not appear to influence breathing pattern in this study. This is contrary to research which found that participants with neck pain were more likely to breathe with an upper-costal breathing pattern compared to participants without neck pain (Halim et al., 2016). Another study reported that people with a faulty breathing pattern were more likely to have neck pain (Perri and Halford, 2004). The difference in findings in the present study may be due to the way in which breathing pattern was determined.

In the studies mentioned, breathing pattern was determined by observation, or a combination of observation and palpation, with the participant in a standing position. In these studies, the participant stood with feet slightly apart facing forward. The examiner would then observe the breathing pattern from the front and side. In some cases, they would place their hands on the participants thorax to feel breathing movement. Although this is a common way of determining breathing pattern, the researcher was concerned that it may lead to bias as it relies entirely on the interpretation of the examiner, and in the current study the researcher was not blinded to the groups. By diagnosing breathing pattern by CTMT ratios, the researcher hoped to minimise bias, as the diagnosis would be based on objective and quantifiable measurements. The rational was that breathing patterns are based on the difference in movement between the upper and lower thorax during inspiration (Celhay et al., 2015), and Halim et al. (2016) reported a strong correlation between thoracic expansion measurements and breathing pattern. However, this method does not account for any vertical movement of the chest during inspiration. Kaneko and Horie (2012) suggest, due to breathing motion being multidirectional, that expansion needs to be assessed on multiple planes.

In the current study, breathing pattern was evaluated in a sitting position. This is different to most other studies that evaluated breathing pattern in standing and this difference in position could have contributed toward the difference in results. Further research needs to be done to validate a method of determining breathing pattern that takes into consideration the multi-planar movement of breathing minimising the risk of testing bias. The influence of posture on thoracic expansion and breathing pattern should also be further investigated.

5.3.4 The Nijmegen Questionnaire (NQ) and Self-Evaluation of Breathing Questionnaire (SEBQ)

In the current study, participants with neck pain reported more symptoms of dysfunctional breathing than those in the control group and were more likely to be diagnosed with dysfunctional breathing according to the NQ and SEBQ. The moderate association between the dysfunctional breathing symptom-questionnaires (NQ and SEBQ) and the NDI, but no or fair association with pain, reveals that these symptoms were more related to reported activity-limitations than pain.

The NQ questions give an indication of symptoms associated with hypocapnia, breathing difficulty and the psychological component of respiration (Courtney and van Dixhoorn, 2014; van Dixhoorn and Folgering, 2015). The main factors assessed with the NQ are the biochemical and psychological components of dysfunctional breathing (Courtney and Greenwood, 2009). Therefore, the results of the current study confirm the link between these aspects of dysfunctional breathing and neck pain. The NQ correlated more with neck disability than pain confirming the link with the psychosocial activity-limiting component of neck pain. This could lead to an increase in respiratory rate (see section 5.3.1) and possible biochemical changes. Hypocapnia is common in people with chronic neck pain (Dimitriadis et al., 2013b; Dimitriadis et al., 2016; McLaughlin et al., 2010) and has been reported to correlate with psychological aspects of neck pain (Dimitriadis et al., 2013b). This may be a result of self-induced hyperventilation as a pain-relieving strategy (Dimitriadis et al., 2013b).

The difference of SEBQ scores between the groups was greater than the difference of the NQ scores. The SEBQ also had a stronger correlation with neck disability and pain intensity than the NQ. The SEBQ addresses both perception and sensation of breathing restriction, which may be related to biochemical and biomechanical components of dysfunctional breathing (Courtney and Greenwood, 2009).

The SEBQ has 25 questions and the NQ only has 16 questions. A recent study reported that one of the questions of the NQ (stiff fingers or arms) was not consistent with the list of symptoms given by experts and patients with experience of hyperventilation syndrome, and that there were many other reported symptoms not included in the NQ (Li Ogilvie et al., 2019). However, they did report that despite the structural validity being poor, most of the symptoms listed by experts and patients with hyperventilation experience could be categorised under the other 15 questions. Therefore, they conclude that the questionnaire is still valid for assessing hyperventilation (Li Ogilvie et al., 2019). This study, however, did not test CO_2 levels, so the extent of biochemical hyperventilation related to these symptoms is unknown. Furthermore, the NQ has been reported not to be specific to hyperventilation syndrome but may be positive with conditions unrelated to respiration (Courtney and van Dixhoorn, 2014). The SEBQ contains more questions relating to respiration and is thought to assess mechanical breathing restriction related to hyperventilation-related hyperinflation (Courtney and Greenwood, 2009). As there is no gold standard for assessing dysfunctional breathing, it is difficult to fully determine the validity of either the NQ or SEBQ. Both questionnaires may be useful in assessing dysfunctional breathing in patients with neck pain. However, taking into consideration the results of this study, the SEBQ may be more specific to respiratory changes associated with mild neck pain.

5.3.5 Breath Hold Time (BHT)

Although there was no significant difference in BHT between those with and without neck pain, it may be clinically relevant that there were more than double the number of participants (n=11) with neck pain who had a BHT of less than 20 seconds (diagnostic criteria for dysfunctional breathing) than participants without neck pain (n=5). Participants with hypocapnia have been reported to have short BHT in some studies (Jack et al., 2004) but not in others (Kiesel et al., 2017). No correlation was found between BHT and CO_2, NQ or SEBQ scores (Courtney and Cohen, 2008; Courtney et al., 2011). Therefore, even though BHT has been reported to detect dysfunctional breathing (Courtney, 2014), it is not necessarily related to other tests of dysfunctional breathing and may not be the most appropriate test for evaluating dysfunctional breathing in people with mild neck pain.

5.4 Muscle activity

5.4.1 Muscle activity in relation to neck pain and disability

Neither neck pain nor neck disability appeared to have an influence on muscle activity of the scalene and sternocleidomastoid muscles in this study. Neck muscle activity, including the sternocleidomastoid and scalene muscles, has been reported to be increased in participants with neck pain (Santanter et al., 2000; Falla et al., 2004; Jull et al., 2004; Cagnie et al., 2011) and a positive correlation between muscle activity of the sternocleidomastoid muscle and pain intensity has also previously been reported (O'Leary et al., 2011). The different results found in this study may be due to the participants of the current study reporting relatively mild pain, possibly minimising the effect of pain on sEMG readings. Another reason for the differences in results may be because the current study measured sEMG in a different posture and during a different activity to other studies.

Studies that investigated muscle activity in participants with neck pain, performed EMG testing in a side-lying position (Santanter et al., 2000) or in a supine position during a CCFT (Falla et al., 2004; Jull et al., 2004; Cagnie et al., 2011; O'Leary et al., 2011). Surface electromyography (sEMG) reliability studies for sternocleidomastoid and scalene muscles performed sEMG measurements in a supine position using isometric movements (Falla et al., 2002a) and in a standing position during functional upper limb movements (Kallenberg et al., 2009). In the current study, sEMG was measured with the participant in a sitting position. Besides breathing, the participant was not required to perform a task such as the CCFT, isometric movement or functional upper limb movement. Therefore, we can suggest that in a sitting position, mild neck pain does not have a significant influence on sternocleidomastoid and scalene muscle activation during quiet or deep breathing.

In the current study, participants were sitting with no head support, so the neck muscles may have been activating in postural control as well as in breathing. No baseline muscle activity or expiratory muscle activity was recorded and, therefore, the influence of postural activation could not be determined. Increased sternocleidomastoid and scalene muscle activity are associated with reduced muscle activity of the deep neck flexors in participants with neck pain, measured in supine during a CCFT (Jull et al., 2004). This indicates that the superficial neck muscles may compensate for weakness or poor activation of the deep postural muscles. However, this may not be the case with a forward head posture, commonly reported in people with neck pain (Yip et al., 2008; Silva et al., 2009; Nejati et al., 2014). Reports of neck sEMG in relation to a forward head posture vary, with some studies reporting reduced activation of the sternocleidomastoid muscle in people with a forward head posture during deep breathing (Han et al., 2016), and others reporting increased sEMG of sternocleidomastoid and anterior scalene muscle during normal breathing (Kang et al., 2018). Therefore, muscle activity of the sternocleidomastoid and scalene muscles may vary according to neck and head posture.

Studies have consistently shown that people with a forward head posture and those with neck pain have reduced respiratory function and strength (Kapreli et al., 2009; Wirth et al., 2014; Dimitriadis et al., 2014; Han et al., 2016; Kang et al., 2018;; López-de-Uralde-Villanueva et al., 2018). Increased neck muscle activity is associated with increased inspiratory pressures (Washino et al., 2019) and increased FVC (Kang et al., 2018). This implies that increased muscle activity occurs with increased strength of contraction. However, early recruitment of the scalene and sternocleidomastoid muscles during inspiration occurs with breathing restriction, respiratory weakness and dyspnoea (Chiti et al., 2008; Washino et al., 2019). Therefore, an increase in muscle activity could either be due to a strong respiratory contraction or muscle dysfunction, depending on how it is interpreted. In this study an average sEMG reading was recorded over a set period without taking into consideration the timing of muscle recruitment which could have contributed toward the similarity between the groups.

The timing of muscle activation and motor unit recruitment is also influenced by the speed of action (in this case inspiration), with muscles eliciting increased motor unit recruitment during faster actions (Costa et al., 1997; Merletti et al., 2001; Roberts and Gabaldón, 2008). To control the speed of inspiration, the researcher determined a set time for inspiration and expiration during deep breathing. However, if time is kept constant, a deep breath for someone with a large lung capacity may require a faster action of inspiration to reach full lung capacity than someone with a smaller lung capacity. This is based on the formula, s=d/t (speed equals distance divided by time). If time is constant and distance of thoracic expansion increases, the speed of contraction will also increase. Therefore, the speed of muscle contraction may have varied between participants in this study based on lung capacity and this may have influenced the results.

5.4.2 Muscle activity with thoracic expansion

The CTMT may give an indication of lung capacity and respiratory strength (de Cordoba Lanza et al., 2013; Debouche et al., 2016). In the current study, sEMG did not correlate with CTMT during quiet or deep breathing. According to the researcher's knowledge, there are no previous studies investigating sEMG of neck muscles in relation to the CTMT. Halim et al. (2016) report that participants with neck pain demonstrate reduced thoracic expansion, especially in the lower thoracic area, and suggests that lack of lower thoracic expansion results in overuse of the neck accessory muscles. Perhaps this may be true during increased respiratory demand, but our study did not find that reduced lower thoracic expansion correlated with increased muscle activity during breathing at rest. Increased sEMG of the scalene and sternocleidomastoid muscles may also be related to increased inspiratory strength (Washino et al., 2019). Therefore, sEMG may be positively associated with thoracic expansion in some people due to increased inspiratory strength, and positively associated with pain in others who have reduced thoracic expansion.

5.4.3 Muscle activity and breathing pattern

In the present study, breathing pattern did not influence sEMG of either sternocleidomastoid or scalene muscle during quiet breathing. Valenzuela et al. (2017) reported increased activity of the sternocleidomastoid during quiet breathing for those who breathed with an upper-costal breathing pattern compared to a costo-diaphragmatic breathing pattern. However, most studies report no significant difference in sternocleidomastoid muscle activity at rest between people with different breathing patterns (de Mayo et al., 2005; Celhay et al., 2015; Miralles et al., 2016).

The current study found that, for participants without neck pain, breathing pattern did not influence sternocleidomastoid or scalene muscle activity during deep breathing. In the neck pain group, however, participants with a costo-diaphragmatic breathing pattern demonstrated greater scalene muscle activity during deep breathing ($p=0.033$). This is contrary to previous research that reported increased muscle activity of both scalene and sternocleidomastoid muscles during deep breathing in people with an upper-costal breathing pattern compared to those with a costo-diaphragmatic breathing pattern (Koh and Jung, 2013). Other studies that investigated sternocleidomastoid muscle activity with deep breathing reported no difference in activity between breathing patterns (Celhay et al., 2015; Miralles et al., 2016).

The reduction in scalene muscle activity in participants with upper-costal breathing pattern, and the negative association between lower thoracic expansion and neck disability reported in this study, could indicate reduced respiratory muscle strength in those with increased levels of disability. Therefore, those participants with higher neck disability demonstrated reduced lower thoracic expansion during deep breathing and may have reduced activation of their respiratory muscles including the diaphragm (indicated by reduced expansion) and the scalene muscle (indicated by reduced muscle activity in participants with upper-costal breathing pattern). However, this does not apply to the whole sample as muscle activity was not associated with thoracic expansion or neck disability.

The method of determining breathing pattern in the current study differed from other studies (as described in section 5.3.3). Increased neck muscle activation may occur more during vertical chest movement which was not assessed in the method used. In the current study, muscle activity was measured in a sitting position. Studies that investigated neck muscle activity during breathing in relation to breathing pattern, did so in sitting with the head supported (de Mayo et al., 2005) and the standing position during a 10-second breath-hold (Celhay et al., 2015). Methods assessing muscle activity of the sternocleidomastoid and scalene muscles during breathing vary considerably and more research is needed to be done to standardise a testing method.

5.5 Perceived stress

5.5.1 Perceived stress in relation to neck pain and disability

The lack of association between neck pain and perceived stress, and the weak association of perceived stress with neck disability, was unexpected, considering the literature supporting the link between neck pain and psychosocial factors (Linton, 2000; Demyttenaere et al., 2007; Karels et al., 2007; Blozik et al., 2009; Dimitriadis et al., 2015; Kim et al., 2018; López-de-Uralde-Villanueva et al., 2018). This could be due to the current study assessing different psychological factors than previous studies, or because of specific characteristics of the participants in this study.

The PSS is moderately to strongly correlated to anxiety and depression (Lee, 2012). In reviews investigating risk and prognostic factors of neck pain, psychological and social measures were grouped into one category (psychosocial factors). When these factors were separated, most related to social support and family or work environment, with few evaluating psychological factors such as depression, anxiety or stress (Karels et al., 2007, Kim et al., 2018). Studies that reported increased depression or anxiety in people with neck pain, have used assessment tools such as the Hospital Anxiety and Depression Scale (Blozik et al., 2009; Dimitriadis et al., 2015; López-de-Uralde-Villanueva et al., 2018) and standardised assessments for diagnosing anxiety and mood disorders (Demyttenaere et al., 2007). Metikaridis et al. (2017) reported that stress-reducing intervention reduced stress and anxiety in participants with neck pain according to the DASS21 ($p=0.03$; $p=0.03$) but did not significantly influence the PSS-14 ($p=0.5$). The PSS assesses perceived stress with two main factors of perceived distress, and perceived self-efficacy (Roberti et al., 2006; Lavoie and Douglas, 2012; Smith et al., 2014; Taylor, 2015; Lee and Jeong, 2019). Perhaps these factors are not as prevalent in people with neck pain as other psychological factors assessed with other psychological assessment tools.

Another possible reason for the poor correlation between neck pain and PSS in this study was that most of the neck pain participants had mild neck pain and mild disability which was not limiting their activities of daily living. Both depression and anxiety have been reported to correlate significantly with neck disability and are more likely to occur in those with high levels of neck pain (Blozik et al., 2009). This is confirmed by Dimitriadis et al. (2013b), who reported that participants with chronic neck pain of mild to moderate intensity and mild disability, did not have increased anxiety or depression compared to the control group.

In the present study, the researcher did not specify duration of reported neck pain. Increased pain and disability are frequently associated with chronic pain (Linton, 2000; Demyttenaere et al., 2007; López-de-Uralde-Villanueva et al., 2018). In two of the studies that assessed depression and anxiety in people with neck pain, the neck pain group consisted of participants who had experienced neck pain for longer than three months (Demyttenaere et al., 2007; López-de-Uralde-Villanueva et al., 2018). However, in Blozik et al. (2009) the duration of neck pain was also not specified. As the duration or extent of recurrence of neck pain was not included in the assessment or inclusion criteria for this study, its influence on the results is unknown.

5.5.2 Perceived stress with breathing outcomes

Stress and anxiety have been reported to result in an increase in respiratory rate (Wilhelm et al., 2001) and even unpleasant images have been shown to increase respiratory rate (Chenivesse et al., 2014). However, in the current study, no significant correlation between the PSS and respiratory rate was found. This may be due to the PSS giving a general indication of stress over the preceding month which did not reflect the current acute stress levels during testing, which were likely to be mild as the participants were assessed in a non-threatening environment.

People with anxiety or panic disorder may have high NQ scores (Agahe et al., 2012) as well as reduced CO_2 levels (Jack et al., 2003; Meuret and Ritz, 2010). In the current study, the PSS correlated moderately to strongly with the NQ ($r>0.5$, $p<0.0001$) and SEBQ ($r>0.5$, $p<0.0001$). This supports the link between psychological influences and dysfunctional breathing. This link may be due to the action of the sympathetic nervous system, activated during a stressful experience, in stimulating breathing irregularities and inducing hypocapnia (Wilhelm et al., 2001; Sikter et al., 2009; Chaitow et al., 2014b; Gilbert, 2014a).

There are no previous studies evaluating the association between the PSS and BHT, therefore the lack of association found in this study cannot be compared with other literature. It has been reported that participants with panic disorder have a shorter BHT than healthy controls (Rassovsky et al., 2006; Nardi et al., 2009) which may indicate that BHT is only affected with certain psychological conditions but not others. Panic disorder and perceived stress as determined by the PSS are different conditions with varying symptoms.

5.6 Confounding variables

Neck dysfunction has many associated risk factors (Cohen, 2015; Blanpied et al., 2017), and breathing is a complex action with biomechanical, biochemical and psychological components (Chaitow et al., 2014b; Courtney, 2016). Therefore, it was necessary that potential confounding variables were investigated. Most of the confounding variables were determined by simple questions in the researcher's questionnaire and were not comprehensively assessed.

5.6.1 Body mass index (BMI)

Body mass index (BMI) did not seem to be related to neck pain in this study as there was no significant difference in BMI between the neck pain and control group. There are some studies that have reported a positive association between BMI and neck pain (Cohen, 2015). However, many reviews do not consider obesity to be a risk or prognostic factor in neck pain (Blanpied et al., 2017; Hurwitz et al., 2018b), and others state that it has no influence on the prevalence of neck pain (Hog-Johnson et al., 2008).

5.6.2 Asthma or chest problems

There was no difference in reported asthma or chest problems between those with and without neck pain. Previous studies report that adults with asthma are more likely to have a forward head posture and pain in the thoracic, cervical or shoulder region compared to non-asthmatics (Lunardi et al., 2011). The reason why there were not more people with asthma in the neck pain group of the current study may have been that the researcher only included participants with well-controlled asthma, excluding those who had an exacerbation of asthma in the preceding six months. People were also excluded if they had any other current chest pathology.

5.6.3 Anxiety or depression medication

Although there were more participants in the neck pain group (n=11) than in the control group (n=5) taking medication for anxiety or depression, there was no statistical relevance to these results (p=0.171) when analysed in the sample of 98 participants. This information was retrieved from a question on the researcher's questionnaire, in which the participants were not required to specify length of medication use, dosage or what the medication was specifically prescribed for. Therefore, these results cannot be interpreted in relation to other literature. The researcher hoped to use this question to gain knowledge into the number of participants with anxiety or depression in the study. However, no conclusive evidence can be drawn from these results.

5.6.4 Nasal congestion or allergies

To the researcher's knowledge, this is the first study to report on increased nasal congestion, sinus problems or allergies in people with neck pain. Migraines are strongly associated with neck pain (r=0.32, p<0.0001) (Calhoun et al., 2010), and a high percentage of people who experience migraines also indicate a history of allergic rhinitis and sinus problems (Erros et al., 2007). Therefore, allergies migraines and neck pain may be related.

In studies investigating mouth breathing in children, significantly more children who breathed through their mouth presented with a head forward posture, increased cervical-occipital extension and reduced cervical lordosis compared to those who breathed nasally (Cuccia et al., 2008; Okuro et al., 2011). Mouth breathing in children is often caused by allergies including allergic rhinitis (Reshma and Baranwal, 2018). Postural changes associated with childhood mouth breathing could affect the development of bony structures in the neck and jaw regions (Cuccia et al., 2008). This may be why a forward-head posture in adults is more prevalent in those who have had a history of mouth breathing as a child (Milanesi et al., 2011). Therefore, allergies, sinus or nasal congestion may contribute to the development of a head-forward posture and predispose one to developing neck pain. In addition, current allergies that require frequent sniffing or nose blowing may require activation of scalene or sternocleidomastoid muscles as well as put mechanical strain on the spine. In the current study this finding was based on one question in the researcher's questionnaire, therefore interpretation and generalisation of this finding is limited.

5.6.5 Exercise

In the present study, participants with neck pain exercised less frequently than those without neck pain, supporting other research reporting that infrequent exercise is associated with increased levels of neck pain (Blozik et al., 2009) and that those who exercise regularly may have a better prognosis (Hog-Johnson et al., 2008). A recent systematic review and meta-analysis reported moderate quality evidence that exercise programs reduce the risk of first onset neck pain (de Campos et al., 2018).

The type of exercise done did not differ between the groups, although more participants in the neck pain group cycled (18 participants) compared to the control group (10 participants), which may be of some clinical relevance. In previous studies, it was reported that people with neck pain who cycle regularly may have a poorer prognosis (Carrol et al., 2008; Blanpied et al., 2017), possibly due to the sustained lordotic posture of the neck during cycling which puts strain on the facet joints (Bell-Jenje, 2011). In the current study, neither the frequency or duration of cycling was compared between the groups and therefore the influence of regular cycling on the presence of neck pain cannot be evaluated.

5.6.6 Computer work

The number of hours spent at a computer per day did not appear to influence neck pain in this study. This is contrary to some findings that report an increased incidence of neck pain with computer use (Cohen, 2015). An attempt to investigate the participants' occupation was made in the researcher's questionnaire to determine occupational risks. However, many of the answers that were given were vague such as "business owner" and did not enable the researcher to categorise the occupational activities or risks. Therefore, no data analysis was performed on the occupational activities or risks of the participants and the occupational risks of this sample is unknown.

6 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

6.1 Conclusions

In conclusion, this research confirms previous research that has reported a link between neck pain and breathing. This relationship was confirmed through two breathing questionnaires which assessed symptoms of dysfunctional breathing: the NQ and SEBQ. Both the NQ and SEBQ scores were higher in the neck pain group compared to the control group. The NQ and SEBQ were moderately to strongly correlated with neck disability in the neck pain group, as well as with perceived stress in both the neck pain group and the control group. In addition, the SEBQ correlated fairly with current pain and the sum of best, worst and current pain.

Contrary to previous research, chest expansion and breathing pattern were similar in participants with neck pain and in control participants. These findings may be due to the method in which the breathing expansion and pattern were determined, or the mild pain and disability reported by the neck pain group. Other breathing assessments included respiratory rate and BHT, both of which were similar in the neck pain group and the control group.

Muscle activity of the sternocleidomastoid and scalene muscles were similar in both groups during quiet and deep breathing. The muscle activity did not correlate with thoracic expansion or differ between breathing patterns during quiet breathing. There was a slightly increase in scalene activity in the neck pain group for participants with a costo-diaphragmatic breathing pattern during deep breathing. The sternocleidomastoid muscle activity during deep breathing was similar between breathing patterns.

Perceived stress was similar in participants with and without neck pain and did not correlate with current pain or the sum of best, worst and current pain. There was a fair correlation between the PSS and NDI. Both the NQ and SEBQ showed moderate to strong correlations with the PSS in those with and without neck pain, confirming the relationship between psychological factors and dysfunctional breathing.

This research has investigated the relationship between neck pain and measures of breathing and has concluded that self-reported symptoms of dysfunctional breathing, assessed using the NQ and SEBQ, were more present in participants experiencing neck pain. The NQ and SEBQ were associated with neck disability as well as with perceived stress.

6.2 Strengths of this study

The variety of measuring instruments utilised in this study to assess neck dysfunction as well as breathing ensured that the relationship between neck pain and breathing was thoroughly assessed, improving the validity of the results. All the assessment tools utilised in this study are easy to use and easily accessible, making the results relevant to health professionals working with limited resources. Furthermore, this is the first research to evaluate easily accessible measures of dysfunctional breathing such as the NQ, SEBQ and BHT in people reporting neck pain. The inclusion of a control group increased the strength of the study, ensuring that the results found in the sample with neck pain was related to neck dysfunction and was different from the general population without neck pain. The researcher also included other questions and measurements to ensure that confounding variables did not influence the results. The testing was done in the same order to minimise any variance that could occur related to testing order. The same instructions were given to both the neck pain and control groups to minimise bias.

6.3 Limitations of this study

A few limitations may have influenced the results of this study and are outlined below. These limitations relate to the sampling of participants, the characteristics of the participants, the methodology of testing, and possible areas of potential bias.

The participants of this study were recruited by convenience from a private physiotherapy practice, and from the general public in Johannesburg, South Africa. Participants recruited from the general public were either recruited through word of mouth or through a Facebook post on the researcher's Facebook page. The demographics of people attending this private healthcare facility and who were potential recruitments from the general public, were relatively narrow. Therefore, because of the lack of diversity in participant demographics, the generalisation of the results is limited. People with neck pain who were not attending a healthcare facility were also included in the study, which may have contributed to the mild pain and disability reported by the study participants. Because the pain and disability were relatively mild, the respiratory, neuromuscular and psychological responses contributing towards the relationship between neck pain and breathing may have been less prominent. Furthermore, the lack of variety in pain and disability reporting within the participants of this study limit the ability to compare these findings with other literature.

Regarding the methodology of the research, a few factors may have influenced the results. The limitation of determining a breathing pattern by circumferential expansion is that the vertical movement was not considered in the diagnosis. The CTMT was done with the participant's shirt still on which the researcher reasoned to not have an effect on the actual expansion (being the difference between an inhale and exhale) as long as the tape measure did not shift during the measurement at one level. However, having the shirt on could have reduced the accuracy of tape measure placement. During the CTMT posture was not controlled for and not corrected, therefore this may have also influenced the pattern and expansion.

During measurement of the muscle activity, posture was not controlled, and timing of muscle recruitment was not investigated. Therefore, an average increase in sEMG readings could indicate a stronger muscle contraction or muscle dysfunction relating to breathing or posture. The researcher chose to keep the inter-electrode distance constant during measurement of the muscle activity. However, due to variation in neck length of the participants, the position of the electrodes in relation to the zone of innervation varied between participants and may have affected action potentials.

The researcher was unable to completely remove bias. All the testing was done by the researcher who was aware of which participant was in which group. The researcher was also directly linked to many of the participants in a patient-physiotherapist, colleague, or social relationship. This could have led to bias including coercion bias. The participants were also not blinded to their group as it related to their condition and were educated beforehand regarding the aim of the study. This may have led them to be biased towards some of the subjective reporting. Most of the tests were done in a standardised way and could not be influenced by bias from the researcher. However, performance rating during the CCFT was based on the researcher's observation and, as the researcher was aware of who was in which group, this could have affected the results.

The instructions, information sheets and questionnaires were all in the English language. All the participants were fluent in English; however, English was not every participant's first language which could have impacted their interpretation.

6.4 Clinical recommendations

The results of this study indicate that people with neck pain, including mild neck pain, may experience more symptoms of dysfunctional breathing, and score higher on the NQ and SEBQ, than people without neck pain. The NQ and SEBQ questionnaires are quick and easy to complete and may serve as a useful screening tool to detect dysfunctional breathing in people with neck pain. Taking into consideration the results of this study, the SEBQ may be especially useful in identifying dysfunctional breathing in relation to mild neck pain. The NQ and SEBQ may also serve as useful outcome measures where respiratory exercises are integrated into physiotherapy treatment for neck pain. Previous research that implemented breathing exercises as part of a treatment regime for chronic neck pain have reported favourable results (Mclaughlin et al. 2010; Mohan et al., 2016; Wirth et al., 2016). These studies assessed breathing using lung function tests and capnography. The current study provides an alternative assessment method for evaluating breathing in patients experiencing neck pain, as well as an alternative outcome measure to evaluate treatment progress involving breathing rehabilitation.

6.5 Recommendations for future studies

Further research is recommended to determine if the results of this study can be generalised to other countries and in varied demographic populations. Studies should also be done to investigate the relationship between neck pain and breathing in participants with more severe neck pain, using subjective and objective assessments. This may help determine the usefulness of clinically accessible physical tests in evaluating breathing in people with neck pain. Further research is also recommended to determine whether neck pain duration influences the relationship between neck pain and breathing, analysing the relationship of acute neck pain with breathing outcomes and comparing this to chronic neck pain with breathing outcomes.

The influence of posture on thoracic expansion and breathing pattern needs to be established. Further research is needed to validate a method of determining breathing pattern that takes into consideration the multiplanar movement of breathing, minimising the risk of testing bias. The relationship of neck dysfunction with breathing pattern and CTMT should be further investigated and confirmed in both sitting and standing positions. Respiratory irregularities and not just respiratory rate should be evaluated in relation to neck pain and breathing outcomes.

Regarding sEMG, further research needs to be done evaluating neck muscle activity during breathing in a sitting position, in relation to neck dysfunction. Evaluating baseline muscle activity and timing of muscle recruitment may give more information of possible dysfunction. Further research investigating muscle activity during a stressful work task or during exercise in relation to other breathing and neck-dysfunction outcomes, is also recommended.

Investigating more than one psychological measure in people with neck pain and analysing this in relation to breathing outcomes would be valuable in determining what psychological factors may be contributing towards the relationship between neck pain and breathing.

A variety of neck strength testing should be investigated in people with neck pain in relation to breathing measures. This will help determine which muscles are contributing towards the muscle dysfunction associated with neck pain and associated breathing symptoms.

In order to apply the results of this study to clinical practice, further research needs to look at determining if the SEBQ or NQ can be used as outcome measures in detecting improvement of breathing-related symptoms in people with neck pain.

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8 APPENDIX LIST

Appendix A: Request letter Samantha Dunbar Incorporated

Dear Samantha Dunbar and Rodger Trent

I am doing research to investigate the relationship between neck pain and breathing. This research aims to investigate various measures of breathing, as well as activity and strength of neck muscles in relation to breathing in people experiencing neck pain. This will help us to determine possible contributing factors to neck pain which will assist in better assessment and treatment strategies.

Request of participation:

I am requesting to use patients from your outpatient physiotherapy and biokinetics facility for this study. I am looking for patients between the ages of 20 and 60 attending the practice for neck pain. I am requesting that I am notified, with permission of the patients, of the people attending the practice for neck pain and have permission to contact these patients.

What is required of the patients?

The patients will be required to meet me at a convenient location. If you are willing to offer your facility as a testing location this would be appreciated. During the meeting, the participants will be asked to fill out a few quick questionnaires, then perform two tests to analyse breathing. Further tests include measuring neck muscle activity using surface EMG and a cranio-cervical flexion test using a pressure biofeedback. Because this is a cross-sectional study, they will not be required to come for any follow-up sessions and there will be no intervention. All testing is non-invasive and completely safe. Participants may choose not to participate or withdraw at any point during the study without penalty or loss of benefits. Recommendations and advice will be given to the treating therapist based on the results.

Confidentiality:

All personal information from the study will be kept confidential. Only the researcher will be able to see personal details, and this will be used for research purposes only. If the treating health professional wants a copy of their patients results, it may be communicated with permission of the patient.

Contact details of researcher: If you have any queries, please call me on 082 881 3459 or email sstephenphysio@gmail.com.

Kind Regards

Sarah Stephen (Bsc. Physiotherapy)

Consent Form

I __Samantha Dunbar_____agree to allow Sarah Stephen to use patients in Samantha Dunbar Inc. practice for her MSc. research study. I understand what is required of me, the department and the patients, and will communicate any questions or specifications if I have to her.

Date: __7/03/2019

Place: ____Randpark Ridge

Signature: 

Appendix B: Ethical approval

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Office of the Deputy Vice-Chancellor (Research & Post Graduate Affairs)

TO: Ms S Stephen
School of Therapeutic Sciences
Department of Physiotherapy
Medical School
University

E-mail: sstephenphysio@gmailcom

CC: Supervisor: Dr C Brandt and Professor B Olivier <Benita.Olivier@wits.ac.za> and <HREC-Medical.ResearchOffice@wits.ac.za>

FROM: Iain Burns
Human Research Ethics Committee (Medical)
Tel: 011 717 1252

E-mail: Iain.Burns@wits.ac.za

DATE: 2019/06/10

REF: *R14/49*

PROTOCOL NO: **M190352** *(This is your ethics application study reference number. Please quote this reference number in all correspondence relating to this study)*

PROJECT TITLE: *The relationship between neck pain and breathing and the role of the sternocleidomastoid, anterior scalene and upper trapezius muscles in breathing and neck pain*

Please find attached the Clearance Certificate for the above project. I hope it goes well and that an article in a recognized publication comes out of it. This will reflect well on your professional standing and contribute to the Government funding of the University.

MSWorks2000/Iain0007/Clearscan.wps

Appendix C: Change of title approval

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
Tel: 02711 7172076

Reference: Mrs Sandra Benn
E-mail: sandra.benn@wits.ac.za

18 February 2020
Person No: 620729
TAB

Mrs C Brandt

Dear Mrs Brandt

Sarah Stephen: Change of title of research

This is to inform you that approval has been granted for Sarah Stephen to change the title of his/her Dissertation for the degree of **Master of Science in Physiotherapy** as follows:

From:	**The relationship between neck pain and dysfunctional breathing**
To:	**The relationship between neck pain and dysfunctional, and breathing outcomes**

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

Appendix D: Information sheet: neck pain group

INFORMATION SHEET

The relationship between neck pain and breathing

Good Day

Introduction

I (Sarah Stephen) am doing research to investigate the relationship between neck pain and breathing. Breathing is often something that we do not even think of, and is not often addressed in treatment, yet it may be contributing to the pain that we experience. This research aims to investigate the various measures of breathing dysfunction in people with neck pain and compare this to people without neck pain. A secondary focus is to evaluate the muscle activity and strength of neck muscles in relation to breathing in people experiencing neck pain compared with controls. This will help us to determine breathing patterns and muscle dysfunction that may be contributing towards neck pain.

Invitation to participate

I am inviting you to take part in a research study if you are in the age group 20-60 years and are experiencing neck pain. You will not be included in the research if you have been diagnosed with any lung or heart conditions, if you smoke, have a neuromuscular disease or have had operations of the spine, breast, upper abdomen, chest or shoulder.

What is involved in the study?

A meeting with the researcher will be arranged at a convenient time and venue. You will be required to fill out a few quick questionnaires. These include a general questionnaire, a questionnaire related to neck pain, and two questionnaires related to symptoms of breathing dysfunction. Two quick tests will be done to analyse your breathing. For one test you will be required to wear tight fitting clothes. This will be to assess your breathing pattern. The other will require you to hold your breath. The final two tests will assess your muscle activity and strength in the neck muscles. Muscle activity will be measured with surface electrode pads on the skin (surface EMG) and muscle strength will be measured using a pressure biofeedback device. The total time that you are required to be there for will be about 30 - 45 minutes. Because this is a cross-sectional study, you will not be required to come for any follow-up sessions. There will be around 100 people participating in this study from Johannesburg and testing will ideally be done between June and December 2019.

Risks

There are no major risks or side effects to the testing. All testing is non-invasive and completely safe. You may feel slightly lightheaded after the breathing tests. If any of the tests or questionnaires cause you any form of distress, we will provide a debrief session and discuss further management with you providing a referral if necessary.

Benefits

The benefits of this research are that we will better understand possible contributions to neck pain. This may assist in more effective treatment and faster recovery. The results will be explained to you and, with your permission, treatment recommendations will be given to your treating physiotherapist to help improve your treatment.

Participation is voluntary

Participation is voluntary and you may choose to withdraw at any point during the study without penalty or loss of benefits.

Confidentiality

All personal information from the study will be kept confidential. Only the researcher and the researcher's supervisor will be able to see your personal details, and this will be used for research purposes only. Personal information will only be disclosed if required by law. Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Research Ethics Committee and the Medicines Control Council (where appropriate).

Contact details of researcher

If you would like more information about the study, please don't hesitate to call me on 082 881 3459 or email sstephenphysio@gmail.com.

Kind Regards

Sarah Stephen

Appendix E: Information sheet: control group

INFORMATION SHEET

The relationship between neck pain and breathing

Good Day

Introduction:
I (Sarah Stephen) am doing research to investigate the relationship between neck pain and breathing. Breathing is often something that we do not even think of, yet it may be contributing to the pain that we experience. This research aims to investigate the various measures of dysfunctional breathing in people with neck pain and compare this to healthy controls. A secondary focus is to evaluate the muscle activity and strength of neck muscles in relation to breathing in people experiencing neck pain compared with controls. This will help us to identify breathing patterns and muscle dysfunction that may be contributing to neck pain.

Invitation to participate:
I am inviting you to take part in a research study as part of the healthy control group if you are in the age group 20-60 years and do not experience neck pain. You will not be included in the research if you have been diagnosed with any lung or heart conditions, if you smoke, have a neuromuscular disease or have had operations of the spine, breast, upper abdomen, chest or shoulder.

What is involved in the study?
A meeting with the researcher will be arranged at a convenient time and venue. You will be required to fill out a few quick questionnaires. These include a general questionnaire and two questionnaires related to symptoms of breathing dysfunction. Two quick tests will be done to analyse your breathing. For one test you will be required to wear tight fitting clothes. This will be to assess your breathing pattern. The other will require you to hold your breath for as long as you feel comfortable. The final two tests will assess your muscle activity and strength in the neck muscles. Muscle activity will be measured with surface electrode pads on the skin (surface EMG) and muscle strength will be measured using a pressure biofeedback device. The total time that you are required to be there for will be about 30 - 45 minutes. Because this is a cross-sectional study, you will not be required to come for any follow-up sessions. There will be around 100 people participating in this study from Johannesburg.

Risks
There are no major risks or side effects to the testing. All testing is non-invasive and completely safe. You may feel slightly lightheaded after the breathing tests. If any of the tests or questionnaires cause you any form of distress, we will provide a debrief session and discuss further management with you providing a referral if necessary.

Benefits
The benefits of this research are that we will better understand possible contributions to neck pain. This may assist in more effective treatment and faster recovery if you ever experience neck pain. The results will be explained to you and you will be referred to a health care professional if any of the tests are suggestive that it may be for your benefit to do so.

Participation is voluntary
You may choose not to participate or withdraw at any point during the study without penalty or loss of benefits.

Confidentiality:
All personal information from the study will be kept confidential. Only the researcher and research assistants will be able to see your personal details, and this will be used for research purposes only. Personal information will only be disclosed if required by law. Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Research Ethics Committee and the Medicines Control Council (where appropriate).

Contact details of researcher
If you would like more information about the study, please don't hesitate to call me on 082 881 3459 or email sstephenphysio@gmail.com.

Kind Regards

Sarah Stephen

Appendix F: Consent form

INFORMED CONSENT SHEET

I ____ (full name), have read the information sheet and hereby consent to take part in this research. I understand the risks and benefits and understand that I may need to expose certain body areas for some tests.

I am participating in this study voluntarily, and I may withdraw at any point without repercussions. If I have any questions or concerns, I will contact the researcher.

Signature: ________________________________

Date: __________________ Place: ___________________

Appendix G: Pilot study feedback form

Pilot Study Feedback Form **June 2019**

1. **Was the process smooth and efficient?** YES/NO

Explain: ____

2. **Did the research meet your expectations for what was required including time commitment and testing?** YES/NO

Explain: ____

3. **Was there anything that was unclear?** YES/NO

Explain: ____

Any further comments:

____
____
____
____
____

Appendix H: Researcher's questionnaire

No:

Researcher's Questionnaire

Demographic Details:

Age:	**Male/Female**
Occupation:	

Medical Information:

Have you had previous surgeries of the shoulder, neck, back, chest or abdomen? Please specify:	**Are you on any medication for pain, anxiety, depression, respiratory problems or nasal congestion?** Please specify:
Do you generally or currently struggle with nasal congestion, sinus problems, hay-fever, rhinitis or allergies affecting your chest or nasal passages? Please specify:	**Do you smoke?** YES/NO **Have you struggled with asthma as a child or frequent chest problems in the past?** Please specify:
Have you ever been in a car accident or experienced whiplash in your neck? YES/NO	**Are you currently receiving physiotherapy?** YES/NO **If yes, specify what for:** NECK/BACK/HEADACHES/OTHER
Circle the relevant areas where you currently feel pain: NECK/LOW-BACK/MID-BACK/ HEAD/JAW/OTHER	**Circle the areas you have previously experienced pain:** NECK/LOW-BACK/MID-BACK/ HEAD/JAW/OTHER
How often do you exercise a week? NEVER/ 1-3 TIMES/ MORE THAN 3 TIMES	**What type of exercise do you do?** CYCLING/RUNNING/STRENGTH/PILATES/YOGA/ OTHER
How many hours on average do you work on a computer/laptop a day? LESS THAN 3/BETWEEN 3 & 6/BETWEEN 6 & 8/MORE THAN 8	

Please rate your pain using the scale shown:

	Score /10
Current Pain	
Lowest (best) pain over last 24 hours	
Highest (worst) pain over last 24 hours	

Appendix I: Neck Disability Index

Neck Disability Index

Circle the option that MOST applies to your current situation

SECTION 1: Pain Intensity 0. I have no pain at the moment 1. The pain is mild at the moment. 2. The pain comes and goes and is moderate. 3. The pain is moderate and does not vary much. 4. The pain is severe but comes and goes. 5. The pain is severe and does not vary much.	**SECTION 2: Personal Care (Washing, Dressing etc.)** 0. I can look after myself without causing extra pain. 1. I can look after myself normally, but it causes extra pain. 2. It is painful to look after myself and I am slow and careful. 3. I need some help but manage most of my personal care. 4. I need help every day in most aspects of self-care. 5. I do not get dressed, I wash with difficulty and stay in bed.
SECTION 3: Lifting 0. I can lift heavy weights without extra pain. 1. I can lift heavy weights, but it causes extra pain. 2. Pain prevents me from lifting heavy weights off the floor, but I can if they are conveniently positioned, for example on a table. 3. Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned. 4. I can lift very light weights (because of pain). 5. I cannot lift or carry anything at all (because of pain).	**SECTION 4: Reading** 0. I can read as much as I want to with no pain in my neck. 1. I can read as much as I want with slight pain in my neck. 2. I can read as much as I want with moderate pain in my neck. 3. I cannot read as much as I want because of moderate pain in my neck. 4. I cannot read as much as I want because of severe pain in my neck. 5. I cannot read at all (because of the pain).
SECTION 5: Headache 0. I have no headaches at all. 1. I have slight headaches which come infrequently. 2. I have moderate headaches which come in-frequently. 3. I have moderate headaches which come frequently. 4. I have severe headaches which come frequently. 5. I have headaches almost all the time.	**SECTION 6: Concentration** 0. I can concentrate fully when I want to with no difficulty. 1. I can concentrate fully when I want to with slight difficulty. 2. I have a fair degree of difficulty in concentrating when I want to. 3. I have a lot of difficulty in concentrating when I want to. 4. I have a great deal of difficulty in concentrating when I want to. 5. I cannot concentrate at all.
SECTION 7: Work 0. I can do as much work as I want to. 1. I can only do my usual work, but no more. 2. I can do most of my usual work, but no more. 3. I cannot do my usual work. 4. I can hardly do any work at all. 5. I cannot do any work at all.	**SECTION 8: Driving** 0. I can drive my car without neck pain. 1. I can drive my car as long as I want with slight pain in my neck. 2. I can drive my car as long as I want with moderate pain in my neck. 3. I cannot drive my car as long as I want because of moderate pain in my neck. 4. I can hardly drive my car at all because of severe pain in my neck. 5. I cannot drive my car at all.
SECTION 9: Sleeping 0. I have no trouble sleeping 1. My sleep is slightly disturbed (less than 1 hour sleepless). 2. My sleep is mildly disturbed (1-2 hours sleepless). 3. My sleep is moderately disturbed (2-3 hours sleepless). 4. My sleep is greatly disturbed (3-5 hours sleepless). 5. My sleep is completely disturbed (5-7 hours sleepless).	**SECTION 10: Recreation** 0. I can engage in all recreational activities with no pain in my neck at all. 1. I can engage in all recreational activities with some pain in my neck. 2. I can engage in most, but not all recreational activities because of pain in my neck. 3. I can engage in a few of my usual recreational activities because of pain in my neck. 4. I can hardly do any recreational activities because of pain in my neck. 5. I cannot do any recreational activities at all.

Appendix J: Nijmegen Questionnaire

Nijmegen Questionnaire

Indicate how often you feel the following with the scoring: (0) never; (1) rarely; (2) sometimes; (3) often; (4) very often.

	0	1	2	3	4
1. Chest pain					
2. Feeling tense					
3. Blurred vision					
4. Dizzy spells					
5. Feeling confused					
6. Faster/deeper breathing					
7. Short of breath					
8. Tight feelings in the chest					
9. Bloated feelings in the stomach					
10. Tingling fingers					
11. Unable to breathe deeply					
12. Stiff fingers or arms					
13. Tight feelings around the mouth					
14. Cold hands or feet					
15. Palpitations					
16. Feelings of anxiety					

Appendix K: Self-Evaluation of Breathing Questionnaire

The Self Evaluation of Breathing Questionnaire

Indicate how often you experience the following with the scoring: (0) never/not true at all; (1) occasionally/a bit true; (2) frequently/mostly true; and (3) very frequently/very true

	0	1	2	3
1. I get easily breathless out of proportion to my fitness				
2. I notice myself breathing shallowly				
3. I get short of breath reading and talking				
4. I notice myself sighing				
5. I notice myself yawning				
6. I feel I cannot get a deep or satisfying breath				
7. I notice that I am breathing irregularly				
8. My breathing feels stuck or restricted				
9. My ribcage feels tight and cannot expand				
10. I notice myself breathing quickly				
11. I get breathless when I'm anxious				
12. I find myself holding my breath				
13. I feel breathless in association with other physical symptoms				
14. I have trouble coordinating my breathing when I am speaking				
15. I can't catch my breath				
16. I feel that the air is stuffy, as if not enough air in the room				
17. I get breathless even when I am resting				
18. My breath feels like it does not go in all the way				
19. My breath feels like it does not go out all the way				
20. My breathing is heavy				
21. I feel that I am breathing more				
22. My breathing requires work				
23. My breathing requires effort				
24. I find myself breathing through my mouth during the day				
25. I breathe through my mouth at night while I sleep				

Appendix L: Perceived Stress Scale

Perceived Stress Scale

Indicate *how often* you felt or thought a certain way **during the last month** with the scoring:
(0) Never; (1) Almost never; (2) Sometimes; (3) Fairly often; (4) Very often.

	0	1	2	3	4
1. In the last month, how often have you been upset because of something that happened unexpectedly?					
2. In the last month, how often have you felt that you were unable to control the important things in your life?					
3. In the last month, how often have you felt nervous and "stressed"?					
4. In the last month, how often have you felt confident about your ability to handle your personal problems?					
5. In the last month, how often have you felt that things were going your way?					
6. In the last month, how often have you found that you could not cope with all the things that you had to do?					
7. In the last month, how often have you been able to control irritations in your life?					
8. In the last month, how often have you felt that you were on top of things?					
9. In the last month, how often have you been angered because of things that were outside of your control?					
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?					

Appendix M: Recording sheet

Recording Sheet

No:

BMI

Height	Weight	BMI

Respiratory Rate

	bpm
RR	

Chest Expansion

		Insp QB	Exp QB	Expansion	Insp DB	Exp DB	Expansion
Axilla level (cm)	1						
	2						
	3						
	Ave						
Xiphoid level (cm)	1						
	2						
	3						
	Ave						
Type		UC/CD			UC/CD		

Surface EMG activity

Muscle/ Breathing	Quiet breathing	Deep breathing		
SCM sternum		1	2	Ave
Anterior scalene		1	2	Ave

Breath Hold Time

Trial Number	BHT – participant (s)	BHT – researcher (s)	Total
1			
2			
3			
Average			

Cranio-Cervical Flexion Test

	22mmHG	24mmHG	26mmHG	28mmHG	30mmHG
Level & sets /10					
Pain					
Control					