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**CERVICO-MANDIBULAR MUSCLE ACTIVITY IN
FEMALES WITH CHRONIC CERVICAL PAIN:
A DESCRIPTIVE, CROSS-SECTIONAL, CORRELATIONAL
STUDY**

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DECLARATION

I, Patricia (Trish) Lang, hereby declare that this thesis is my own work and has not been submitted for a degree at any other university. All resources I have used or quoted are acknowledged by a complete list of references.

.....
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10 April 2012

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
BMI	Body mass index
BOTOX	Botulinum toxin
BPI	Brief pain inventory
CE	Cervical extensor (superficial muscles: splenius capitis and cervicis)
CMD	Cranio-mandibular disorders
CNS	Central nervous system
CSD	Cervical spine dysfunction
CUQ	Computer usage questionnaire
CV	Craniovertebral angle
EMG	Electromyography
EQ-5D	EuroQol 5D quality of life questionnaire
HADS	Hospital anxiety and depression scale
HRQoL	Health-related quality of life
ICF	International classification of functioning, disability and health
JFS	Jaw functional scale
L	Left
MDQ	McGill Pain Questionnaire pain rating index
MPQ	McGill pain questionnaire
MSC	Musculoskeletal conditions
MVC	Maximum voluntary contraction
NDI	Neck disability index
NMQ	Nordic musculoskeletal questionnaire
NPQ	Northwick park questionnaire
OR	Odds ratio
PI	Principal investigator

PNS	Peripheral nervous system
PSFS	Patient specific functional scale
R	Right
rCSA	Relative cross-sectional area
RDC/TMD	Research diagnostic criteria for temporomandibular disorders
RMS	Root mean square
SA	Republic of South Africa
SCM	Sternocleidomastoid
SD	Standard deviation
sEMG	Surface electromyography
SF-36	36-item short-form health survey
STROBE	Strengthening the reporting of observational studies in epidemiology
TMD	Temporomandibular disorders
TMJ	Temporomandibular joint
TMPDS	Temporomandibular pain dysfunction disorders
UCT	University of Cape Town
UT	Upper trapezius
VAS	Visual analogue scale
WAD	Whiplash associated disorders
χ^2	Chi-squared test

GLOSSARY OF TERMS

Co-morbidity:

Has a dual meaning:

- 1) The presence of co-existing or additional diseases with reference to the index condition that is the subject of study.
- 2) May affect the ability of affected individuals to function, and also their survival (45).

Impairment:

The physiological, physical and psychological measures of loss or abnormality (55).

Disability:

Functional limitation at the body level, activity level and social participatory level (55).

Societal participation:

Handicap based on environmental factors of physical lifestyle, social environment and attitudes (55).

Cervical spine dysfunction (CSD):

A collective term embracing a number of clinical problems of the musculoskeletal structures of the cervical spine, presenting commonly as cervical pain, resulting from macro- or micro-trauma to the joints or periarticular structures surrounding the cervical spine (17).

Non-specific chronic cervical pain:

Chronic pain with or without radiation without a specific systemic disease being detected as the underlying cause of the complaints (71).

Cervical pain:

Pain anywhere vertically between the suboccipital region and the inferior angle of the scapula medially, extending laterally to the upper trapezius and lateral margin of the scapula; referred to as “*regional cervical pain*” (14).

Temporomandibular disorders (TMD):

A group of pathologies that affect the masticatory muscles, the temporomandibular joint (TMJ) and/or related structures in the head and cervical area (122).

Temporomandibular pain dysfunction disorders (TMPDS):

A disorder that requires the occurrence of at least one of the symptoms of pain around the ear area or near vicinity, pain with wide mouth depression, and/or pain in the mandibular muscles of mastication. There should be no clinical or radiological changes in the temporomandibular joint itself (122). This disorder was first described and proposed by Laskin in 1969 (170).

Teeth malocclusion:

A phenomenon that occurs in the presence of either/or deep overbite, prominent or missing incisors, partial or total anterior cross-bite, general anterior or midline spacing, or severe anterior crowding (25,169).

ABSTRACT

Background and purpose:

Chronic musculoskeletal conditions of the spine and periphery are a burden both internationally and in South Africa. There is a socio-economic burden as a consequence of the severity, duration and recurrence of chronic cervical musculoskeletal conditions among information technology and sedentary office workers. However, the precise mechanisms behind chronic cervical disorders remain unclear.

It is theorised that the pathophysiological mechanisms in chronic cervical musculoskeletal conditions share a similar theoretical framework to chronic pain itself. The biopsychosocial model of chronic pain accepts the dynamic nature of pain. This model accepts the dual biological and psychosocial components that enhance the experience and maintenance of chronic pain, through central sensitisation. There appears to be a neurophysiological, biomechanical and psychological link between the cervical area and the temporomandibular area. Although numerous studies have implied that individuals with temporomandibular disorders have concurrent cervical dysfunction, there is currently no evidence that individuals with cervical dysfunction exhibit altered muscle activity in the masseter and cervical erector spinae muscles or report teeth clenching habits. Consequently, identification of factors that may contribute to chronic cervical musculoskeletal conditions, stemming from the temporomandibular area, may potentially be lost.

The aim of the present study was to explore the activity levels of the cervico-mandibular muscles in females with chronic cervical musculoskeletal conditions, who showed no symptoms of temporomandibular disorders.

Method:

This study had a descriptive cross-sectional correlational design with single-blinding. The telephonic screening process was followed by the signing of informed consent forms. Validated questionnaires were used for categorisation and comparison of the socio-demographic and biopsychosocial profiles of the pain group (n = 20) and the no pain group (n = 22). The screening, informed consent and questionnaires were completed by an assistant. The first of five questionnaires, the adapted Research Diagnostic Criteria History questionnaire, was used as an instrument for exclusion of temporomandibular disorders and the recording of a daytime parafunctional teeth clenching habit. The remaining four questionnaires, listed as the Neck Disability Index, the Computer Usage Questionnaire, the Brief Pain Inventory, and the EuroQoL-5D were used for determining levels of cervical disability for categorisation and comparison between groups, as well as for determining levels of pain-related disability, occupational and sporting activity, and health related quality of life.

Surface electromyographic electrodes were placed over bilateral masseter and superficial cervical extensor muscle groups. Surface electromyographic activity of the cervico-mandibular muscles was recorded for 10 seconds in two positions: the sitting position at rest, and the position of first posterior tooth contact (light clench). The surface electromyographic testing was performed by the principal investigator, who was blinded to the groups.

The socio-demographic and biopsychosocial differences between the pain and no pain groups were determined. Cervico-mandibular resting muscle activity and firing pattern during light clench were compared between groups, as well as the relationships between cervical disability, pain, and level of occupational and leisure-related activities. Secondary analysis was conducted using the variables of teeth clenching and anxiety/depression as grouping variables.

Results:

There were no differences in socio-demographic profile between the pain and no pain groups. Significant differences were observed in the biopsychosocial profile of those with and without chronic cervical musculoskeletal pain. Individuals in the pain group reported higher disability ($p < 0.01$), pain ($p < 0.01$), and the presence of a daytime teeth clenching habit ($p = 0.01$) compared to the no pain group. In addition, those in the pain group reported higher health related quality of life sub-sections of pain ($p < 0.01$), a lower perceived health status ($p = 0.02$), and greater levels of anxiety/depression ($p = 0.05$) due to cervical pain. There were no differences in cervico-mandibular activity level at rest or during light clench in those with and without cervical pain.

There were significant relationships observed between the factors of cervical disability and pain for the total sample ($Rho = 0.80$; $p < 0.05$), pain group ($Rho = 0.72$; $p < 0.05$), and no pain group ($Rho = 0.50$; $p < 0.05$). There were significant relationships found between cervical disability and state of health for the total sample ($Rho = -0.35$; $p < 0.05$), yet not per group. However, there was no significant relationship between cervical disability and resting cervico-mandibular electrical activity for the total sample, pain, or no pain group.

Individuals who reported teeth clenching reported higher disability due to cervical pain ($p = 0.02$). In addition, those who reported teeth clenching reported higher values for health-related quality subgroups of pain/discomfort ($p = 0.02$) and anxiety/depression ($p < 0.01$) due to cervical pain. There was no significant difference in resting cervico-mandibular activity between those who did and did not clench. Further, individuals who reported anxiety/depression reported higher disability ($p = 0.01$) and pain ($p < 0.01$) due to cervical pain. In addition, those who reported anxiety/depression reported a lower self-perceived state of health ($p = 0.01$) and a higher prevalence of teeth clenching habits ($p < 0.01$) due to cervical pain. There was no significant difference in resting cervico-mandibular activity between those who did and did not report anxiety/depression.

Discussion and conclusion:

Exploration of the relationship between the cervical spine and the temporomandibular complex has revealed biopsychosocial associations that may contribute to chronic cervical musculoskeletal conditions. In the current study, the lack of cervico-mandibular surface electromyographic findings in relation to the other strong biopsychosocial factors including teeth clenching and anxiety/depression has further highlighted the complex pathophysiological mechanisms found in chronic pain, not limited purely to biomechanical influences. The interactive relationships observed between cervical disability, the presence of teeth clenching, and anxiety/depression alludes to the presence of significant pathophysiological mechanisms that underlie the condition of chronic cervical pain, not limited to the physical nociceptive system. These findings suggest the presence of central sensitisation and central nervous system changes and drivers that occur in the presence of chronic pain and pain-related disability.

The findings of this study highlight the complex interactions between the cervical spine, the temporomandibular area, and biopsychosocial factors such as anxiety and depression. It is recommended that clinicians perform a comprehensive assessment of patients with chronic cervical pain that incorporates the multifactorial nature of this condition. The recommendations following the study include the need to assess and manage the factors of cervical disability, presence of daytime teeth clenching, and anxiety/depression in the clinician's approach toward chronic cervical musculoskeletal conditions. In addition, the descriptive profile of those suffering with cervical disorders could enrich future cohort studies researching cause-and-effect relationships of chronic cervical pain.

CHAPTER 1: INTRODUCTION

1.1 Background

The prevalence and impact of chronic pain in terms of quality of life, disability and economic impact is frequently reported in epidemiological studies. The prevalence of chronic musculoskeletal conditions (MSC) is reported in workers from all occupational categories (1). South Africa (SA) ranks fourth highest worldwide for the combined prevalence of chronic cervical and lumbar pain (2). Yet the aetiology of and mechanisms behind chronic pain, including chronic cervical MSC, are not well understood. Of particular interest in the present study is the presence of chronic cervical MSC in the office workplace (3). The greatest proportion of the SA population with chronic MSC falls within the employed age group of 18 to 49 years (2). Disability for cervical conditions appears to be less common than for lower back pain (3,4). However, cervical MSC ranging from low to high levels of pain and disability has been shown to influence work attendance and productivity, and subsequently has an economic impact on individuals and society (5-8).

The precise mechanisms causing chronic cervical MSC in office workers employed in the information technology sector remain unclear (3). The suggested pathophysiological mechanisms behind chronic cervical pain and pain-related disability seem to mimic any chronic pain condition, in which there may be ongoing central and peripheral components (9,10). Links between the cervical spine and the temporomandibular area have been theorised to influence pathophysiological processing and output of pain, thereby compounding the cycle of chronic cervical pain and pain-related disability. However, whether this is a cause or effect phenomenon is unknown (11-23).

The nature of the co-existence of the two well-known chronic syndromes of cervical MSC and temporomandibular pain dysfunction disorders (TMPDS) remains unclear (21,23-25). Investigations into co-activation of cervico-mandibular muscle activity have been driven by the dentistry profession in its management of temporomandibular disorders (TMD) and particularly TMPDS. However, there remains a paucity of information on the activity levels of the cervico-mandibular muscles in those with chronic cervical MSC who show no symptoms of TMD.

There appears to be a linear relationship in terms of nature and degree of co-activation of the masseter muscle and the cervical flexor muscles during teeth clenching in normal participants (26-28). However, the findings on the interaction between the masseter and cervical extensor muscles are not as clear (26,29,30). It is theorised that the co-activational relationship exists due to neurophysiological interconnections or to cervical postural variables (26,31-38). Hence the significance of the current study would be in its potential to identify factors which contribute to chronic cervical MSC and pain-related disability. The descriptive profile of those suffering with chronic cervical MSC could potentially enrich future cohort studies that aim to examine cause-and-effect relationships.

1.2 Aim

The aim of the study was to explore the activity levels of the cervico-mandibular muscles in females with chronic cervical musculoskeletal conditions, who showed no symptoms of TMD.

1.3 Objectives

The objectives of the study were to measure surface electromyographic (sEMG) activity of the masseter and cervical extensor (CE) muscles in individuals with pain from chronic cervical MSC and in control participants without pain, using:

- a) the sitting position at rest;
- b) posterior tooth contact (light teeth clench).

Further objectives were to explore relationships in those with pain and those without pain between chronic cervical MSC and:

- a) disability;
- b) occupational activities;
- b) leisure-related sporting activities;
- c) teeth clenching habits;
- d) health related quality of life (HRQoL);
- e) sEMG.

1.4 Significance of the study

The relationship between the cervical spine and the temporomandibular complex, which is not well understood, is theorised to include biomechanical, neurophysiological, and psychological components. The exploration of the activity levels of the cervico-mandibular muscles in individuals with chronic cervical MSC, who show no symptoms of TMD, would assist in providing a better understanding of the pathophysiological mechanisms behind the relationship.

The preparatory steps for the descriptive study will involve a framework of the pathophysiological mechanisms of chronic pain in general, as well as in chronic cervical MSC and TMD (Chapter 2). The chapter concludes with the presentation of the relationship between the cervical and temporomandibular areas, as well as the instrumentation used in better describing the relationship between the two areas. This is followed by a chapter on the methodological process of the present study (Chapter 3). Results, discussion and conclusion end the study thesis (Chapters 4 to 6).

CHAPTER 2: LITERATURE REVIEW

Literature will be presented on the theoretical framework for chronic pain using the biopsychosocial model. This model acknowledges the outdated concept of a one-on-one relationship between injury and pain, and confirms the necessary integration of both biological and psychosocial components. In this model, pain is understood to be dynamic, following a varied pattern of predisposition, transition and prognosis from the acute to chronic stages of pain and pain-related disability (9).

The mechanisms underlying chronic pain will provide the background for discussion of the factors contributing to the presence of chronic cervical conditions. The evidence supporting current theories on the aetiology of chronic cervical MSC will be discussed. Factors which may contribute to the development of chronic cervical MSC including biological and psychosocial factors will be reviewed. In particular, the relationship between chronic MSC and TMD will be presented. The literature review will conclude with a review of measurement instruments most appropriate to investigating cervical MSC and TMD, and describing the relationship between chronic cervical MSC and TMD.

A search was performed using EBSCOhost as a platform for full-text research databases. A specific selection of single databases were sourced, listed as Academic Search Premier, Africa-Wide Information, CINAHL, ERIC, MEDLINE, and PsycINFO to cover the disciplines of medicine and psychology. Keywords and terms used in various combinations for the search included “*chronic pain*”, “*musculoskeletal disorders*”, “*chronic cervical pain*”, “*temporomandibular pain*”, “*temporomandibular disorders*”, “*electromyography*”, “*gender*”, “*co-morbidity*”, and “*disability*”.

2.1 Chronic pain

2.1.1 Epidemiology of chronic pain

Epidemiology is the study of the prevalence and cause of a disease, injury, or health-related event in a defined population (39). Evaluation of the prevalence of chronic pain conditions is confounded by inconsistency in the definition of chronic pain as used by different researchers (40,41). Chronic pain has variously been defined as “*pain lasting more than three months*” (42), “*pain lasting more than six weeks*” (43), or as “*pain not distinguished by its duration but by the inability of the body to achieve normal physiological homeostatic levels*” (44), p. 1609. Differences in definition result in researchers using varying methodologies to evaluate the prevalence of the condition (40,41).

In a large nationally representative South African sample, Smuts (2) reported a 48.1% prevalence of chronic pain conditions, a figure similar to those reported in the developed world. The most common chronic pain conditions reported in SA were arthritis/rheumatism (10%) and chronic lower back or cervical pain (26.3%) (2). The latter figure of 26.3% ranks SA prevalence fourth in the world. The epidemiological study by Smuts (2) is statistically significant, having used a large stratified sample. A further strength of the study is that its findings are clinically generalisable to the South African population.

Compounding the difficulties of evaluating the epidemiology of chronic pain conditions is the prevalence of age- and lifestyle-related co-morbid disease in those with non-traumatic chronic musculoskeletal conditions (MSC of the spine and peripheral joints) (40,41). A dual definition for co-morbidity exists: “*the presence of co-existing or additional diseases with reference to the index condition that is the subject of study*”, and “*its existence may affect the ability of affected individuals to function, and also their survival*” (45). Hence, co-morbid conditions present additional challenges in understanding the aetiology of chronic pain conditions.

A large United States survey on adults in households reported that 87.1% of participants with chronic spinal pain had at least one co-morbid condition (46). The authors grouped lifestyle-related co-morbid diseases into “*other chronic pain conditions*” (66.8%), “*chronic physical conditions*” (55.3%), and “*mental disorders*” (35.0%). Correspondingly, investigations into the medical profile of adult South Africans seeking general medical treatment revealed similar findings (2,40). Parker and Jelsma (40) reported that only 6.9% of their sample had MSC in isolation while 33% reported combined MSC and co-morbidity. The degree of disability in those with MSC who also had a co-morbid condition was more severe. Similarly, Smuts (2) revealed a 1.3 times increased risk of presenting with a spinal pain disorder when a mental health disorder is present (alcohol-, depression- or anxiety-related disorder). When all forms of co-morbidity are considered, there appears to be a greater impact on HRQoL in those with MSC and co-morbidity, than either MSC or the co-morbid condition in isolation (46).

The socio-economic burden of chronic pain, which leads to work absenteeism and healthcare expenditure, is well documented (1,8,10,14,47). Logically, where there is combined co-morbidity, the socio-economic burden will be higher, along with additional increases in disability and reduction in HRQoL. There appears to be greater levels of severity of chronic pain (predominantly lower back and cervical/head symptoms) and subsequently greater socio-economic burden in developing countries (3,40,48-50). Figures for prevalence of moderate to severe pain and disability in a developing province such as the Eastern Cape, SA, range from 38% to 74%, whereas in developed countries the prevalence of severity appears lower (1,4,51). For instance, it has been reported that 4.8% of the population in Canada suffer with chronic pain (cervical and related areas) and have severe disability (4). Therefore, the burden of disease due to medical costs and absenteeism appears to be correlated with severity of symptoms (1,4,51).

The nature of the relationship between MSC and co-morbidity remains unclear (40,46). Possible reasons for lack of clarity have been due to self-reporting of co-morbidity rather than through accurate diagnoses. In addition, the aetiology and pathophysiological mechanisms behind chronic pain, both with and without co-morbidity, remain uncertain (3,10,40,46). One could question whether the co-morbidities prevalent in chronic MSC are in themselves maladaptive manifestations of chronic pain. In the following section, a review of the literature on the theoretical framework for chronic pain will be presented.

2.1.2 Chronic pain: a theoretical framework

The mechanisms contributing to chronic pain are complex (10,47). In the past, the (bio) medical model of pain looked in isolation at physical signs and symptoms (impairment) as the source for diagnosis of a condition (52,53). This model of pain has since given way to the biopsychosocial model, which accepted that pain was a dynamic entity and not isolated to signs and symptoms (10,54). The biopsychosocial model employs a dual-axis paradigm of integrating both physical and psychosocial factors, and its clinical applications have led to the development and employment of appropriate outcome measuring tools of impairment, disability, and societal participation (55). However, as discussed earlier, differences in the definition of chronic pain have led researchers to use different methodologies to evaluate both the prevalence and factors contributing to chronic pain (40,41).

According to the biopsychosocial model, contributory factors to chronic pain arise from an integrated psychophysical aspect (54,56). The theoretical framework to this model, according to Loeser and Melzack (44), recognises that these psychophysical aspects may be the mechanisms that underlie the pain, creating long-term changes in the central nervous system (CNS). Psychophysical aspects may include ongoing noxious input as well as external factors acting at the brain level, such as the affective components of previous experience, anxiety, hopes and dreams (44). Therefore, in the presence of chronic pain, both the physical nociceptive system and the non-nociceptive cognitive-evaluative mechanisms create and undergo profound changes, leading to further changes in pain and motor control output ("*the cortical pain neuromatrix*") (44,54).

In addition, the brain is able to generate or augment pain in the absence of nociceptive input from the periphery or spinal cord, as in the case of phantom limb pain and other chronic disorders of paraplegia (9,10,44). By influencing the inputs on the neuromatrix, one is able to positively or negatively influence the output of the neuromatrix. Though cause or effect mechanisms are difficult to determine, it is the integrative action of the CNS and its role with regard to pain, which remains the key to successful assessment and management of chronic pain (44,54,56).

2.1.3 Aetiology of chronic pain

Typical physical and psychosocial risk factors for chronic pain have been identified, including age, gender, genetics, workplace-related ergonomics, and job- and lifestyle-related stressors (1,3,6,48,49,57). In addition, psychological factors may include aspects of coping strategies, interpretation of pain, and fear-avoidance beliefs (46,47,58-60).

Psychological factors, rather than biomedical or biomechanical risk factors, are the more potent predictors of the persistence and future course of chronic pain and long-term disability (47,60). Linton et al (47) made use of a longitudinal study design of individuals from the general population with spinal pain. The investigators observed a strong association between degree of psychological involvement and level of risk for developing long-term work disability. In addition, they highlighted the benefits of a cognitive-behavioural intervention approach in terms of preventing long-term disability in their medium and high risk groups. The strength of their study lies in the longitudinal design (from baseline to 12 months), allowing for the observation of the evolution of acute pain to chronic disability. A further strength lies in the study design, with the research team being blinded to the participant scores during the trials, thus reducing methodological bias. These authors recognised the benefits of early psychosocial screening to prevent chronicity, and highlighted the importance of the correct timing for the intervention. They also indicated to the need for the correct form of intervention. However, the study is weakened by limiting the assessment of participants to psychological aspects only, while not accounting for other factors contributing to persistent disability.

It appears the key to preventing long-term disability associated with chronic pain is the identification of risk factors in the transition period from acute to chronic pain (10,46,47,61). The possible mechanisms for the transition from acute to chronic pain may be related to ongoing peripheral and central stimuli, at any point from the peripheral nociceptors to the cortical neurons in the brain (9,10,44). Therefore, a shift has been recommended towards a better understanding of the pathophysiological biopsychosocial mechanisms behind the maintenance, rather than only the cause of chronic pain (15,47,58). This may assist in increasing the understanding of the multidimensional nature of chronic pain and its chronic forms of presentation or co-morbidity (15,47,58). The pathophysiology of chronic painful MSC will now be discussed to provide a background to the aetiology of chronic cervical pain.

2.1.4 Pathophysiology of chronic pain

Multiple physiological processes from nociception to the experience of pain occur in both acute and chronic circumstances (62). Sensory receptors in the periphery include primary afferent neurons that respond to specific stimuli of mechano- ($A\beta$ fibres), thermo- ($A\delta$ and non-myelinated C fibres) or nociceptors ($A\delta$ and C).

Nociception is a physiological process that involves conversion and transmission of noxious stimuli from the musculoskeletal structures to the spinal cord (part of the CNS). Pain, on the other hand, is a high order CNS output (occurring in the brain) that motivates and assists the individual to change their behaviour to maintain homeostasis. Not all nociception is of a sufficient magnitude or quality to cause pain (44,62,63). Factors that influence the presence and experience of pain include the intensity and persistence of nociceptive input (3,61,64-66). In addition, the perceived threat value of pain, fear, anxiety, and other emotions contribute both to the experience and maintenance of pain (62). Following the onset of nociception, there is potential to create, augment or perpetuate pain, thereby creating a chronic pain cycle (67,68).

Acute pain has a temporal and causal relationship to tissue injury or disease (10,44). When there is tissue damage, the processes that contribute to the experience of pain occur at a peripheral, spinal and cortical level (9,10). At a peripheral level, neurogenic inflammation and peripheral sensitisation are major contributors to nociception. At the level of the spinal cord, several primary afferents may converge on one neuron affecting the processing of information and contributing to central sensitisation. At a cortical level the complex process of evaluation of nociception occurs, producing and enhancing, modulating or inhibiting pain. The primary purpose of acute pain has been proposed to be one of behaviour modification to facilitate rapid healing (69). However, it should be noted that there is no “*fixed*” response to a nociceptive input and subsequently any nociceptive input and resultant response has the potential to become chronic (9,62).

The function of chronic pain has been proposed to be an attempt by the CNS to govern physiological homeostasis through “*protective*” physiological changes in both the peripheral nervous system (PNS) and CNS (44,68). People suffering from chronic pain may present with a range of symptoms including primary and secondary hyperalgesia in the absence of tissue damage, allodynia, referred pain, and pain summation or latency. Changes in the PNS include maintenance of peripheral sensitisation, including an increase in spontaneous activity, a lowered firing threshold, an increase in responsiveness to stimulation, and an increase in receptor field size in the peripheral nociceptors, resulting in primary hyperalgesia and allodynia. In the CNS, maintenance of central sensitisation occurs at the spinal cord and cortical levels, contributing to secondary hyperalgesia and further allodynia. It is theorised that the maintenance of central sensitisation may be as a consequence of ongoing nociceptive input from persistent trauma, altered biomechanics and movement patterns (62). It should be noted that further theories pertaining to the maintenance of central sensitisation, including psychosocial issues such as fear-avoidance and catastrophisation, have been proposed (70). Whatever the cause of central sensitisation, the resultant lowering of thresholds, increased responses to noxious or innocuous stimulus, death of inhibitory neurons, and reorganization of the cortical distribution of impulses that occur in chronic pain, all contribute both to the experience and maintenance of the painful condition (9,10).

The pathophysiological process of chronic pain can thus be ascribed to the maintenance of peripheral and/or central sensitisation. However, it is unclear whether these peripheral and central sensitisation processes are a cause or consequence of chronic pain (9,44). Nevertheless, what is evident is that once chronic pain is diagnosed, pain has occurred past the point of tissue healing and is no longer linked to tissue damage (62). Tunks et al (66) observe that "*Chronic pain does not resolve in the usual time frame and is unresponsive to the treatment that usually relieves pain*", p. 225. Chronic pain is thus a "*disease process*" in itself (10). The chronic condition of cervical MSC will now be discussed.

2.2 Chronic cervical pain

Cervical pain or cervical spine dysfunction (CSD) is a heterogeneous condition. Classification into specific subgroups has aided diagnosis of specific pathologies, and assisted in optimizing relevant outcome measures and management (1,71-74). For instance, classification of CSD according to signs and symptoms of pathology or to mechanism of injury has produced two subgroups: whiplash associated disorders (WAD) and idiopathic non-traumatic chronic cervical pain disorders (such as cervicogenic headache or cervicobrachial pain) (71). As mentioned earlier, CSD classification according to cause and diagnosis does not form part of the biopsychosocial model of pain (52,53). Therefore, the term "*non-specific cervical MSC*" remains sufficient and refers to "*pain with or without radiation without a specific systemic disease being detected as the underlying cause of the complaints*" (71), p. 2. Despite classification into subgroups, the pathophysiological mechanisms behind chronic cervical MSC remain unclear (3,75,76). Literature on the high prevalence of chronic cervical MSC within the general population and among office workers indicates a need for further clarification of the pathophysiological factors that may contribute to this chronic condition. The epidemiology of chronic cervical MSC will now be discussed.

2.2.1 Epidemiology of chronic cervical MSC

Cervical pain is common in the general adult population with some authors describing a 12-month prevalence of more than 20% (4), and others estimating prevalence between 12.1% and 71.5% (1). The wide range in prevalence data for cervical pain may, in part, be due to the limited number of population-based epidemiologic studies done on cervical pain compared to lower back pain (3). Comparatively fewer cervical investigations have been conducted, as disability for cervical pain appears to be less common than for lower back pain (3,4). Furthermore, the wide range in prevalence data for cervical pain may exist due to variations in definition of cervical pain, particularly of chronic cervical pain (3,10,40,46). Previously in Section 2.1.1 (p. 5), it was noted that differences in definition of chronic pain result in researchers using differing methodologies to evaluate prevalence. For instance, systematic reviews on cervical disorders, such as the one by Haldeman et al (1), claim methodological strengths due to their large population samples collected by research institutes across different countries in the US. However, a noticeable methodological weakness of sample bias is present, owing to their use of varying case definitions. In addition, it remains realistic, if problematic, that large population samples necessary for the gathering of prevalence data on cervical MSC are commonly heterogeneous. The population samples vary widely in age, gender, activity level, health status, and psychosocial function which are regarded as contributory factors to cervical conditions (3). This may return a wide range of prevalence data.

Sixty-six percent of adults will experience cervical pain at least once during their lifetime (4). Within the workplace, Haldeman et al (1) reported employees from all occupational categories having an estimated 12-month cervical pain prevalence of 27.1% to 47.8%. In the SA, which at 26.3% ranks fourth in the world for the combined prevalence of chronic cervical and lumbar pain, it is found that the greatest proportion of these individuals fall within the employed age group of 18 to 49 years (2). The prevalence of workplace-related cervical MSC in sedentary office workers involved in information technology is estimated at 31% (33).

Once again prevalence data of cervical pain within the workplace is dependent on the case definition used for cervical pain. Haldeman et al (1) described cervical pain as “*an episodic occurrence with variable recovery between episodes*”, pg. 9, and recommended the need for an improved classification system for cervical pain, according to cervical pain severity. This would aid interpretation of scientific evidence for the purposes of research and management within the workplace.

The literature suggests that the impact of cervical pain should be measured by its propensity to disable individuals and not by prevalence alone (4). We are reminded of the biopsychosocial model of pain when we analyse the definitions stated by the International Classification of Functioning, Disability and Health (55). The results of pain do not appear to be isolated to impairment aspects of physiological, physical and psychological loss or abnormality. Rather, additional influences resulting from pain have been identified as pain-related disability. Disability has been defined as the functional limitation at the body level, activity level and social participatory level (55). Therefore, the clinical relevance to the far-reaching negative effects on society of pain-related disability should not be ignored or underestimated.

The incidence of first onset cervical pain has generally followed a varied course and prognosis. Most individuals are found to have incomplete resolution of symptoms following an initial report of cervical pain (1). A number of authors report that 10% to 37% of individuals with first onset cervical pain have persistence or recurrence of symptoms within 6 to 12 months, and 70% to 80% within one to five years (1,77). In a Canadian study, Cote et al (4) categorised adult cervical MSC sufferers according to a hierarchical grading of disability, using the psychometric Chronic Pain Questionnaire (78). The investigators observed that only 2% to 11% suffered from “*severe disability*” (i.e.: low-disability high-intensity), yet as many as 18% of those with chronic cervical MSC sought treatment.

Methodological limitations exist to the study by Cote et al (4). While the Chronic Pain Questionnaire has been validated for previous MSC conditions of low back, headache and TMD (78), it had not been validated for cervical pain studies (4). Further, although the study sample was proposed to be a representative sample of the Saskatchewan adult population, the questionnaire had sample selection response bias, specifically toward the lower grades of severity. The prevalence results should therefore be interpreted with caution. Nevertheless, the data by Cote et al (4) highlighted the impact of perceived disability, even at low levels, on the individual and the socio-economic environment. Their findings are supported by a recent study by Parker and Jelsma (40).

Parker and Jelsma (40) reported that people presenting with spinal MSC and associated co-morbidity at a primary health care clinic in SA suffered from mild to moderate disability. Strengths of the study by Parker and Jelsma (40) were its use of validated questionnaires in English, Afrikaans and isiXhosa, overcoming limitation pertaining to language. Yet weaknesses arose due to lack of completion of later-phase questionnaires for data collection on burden of disease. In addition, as the study sample was collected from two clinic-based populations, the results obtained were not a complete representation of the prevalence of MSC in lower socio-economic communities of SA. Notwithstanding the presence of varying study limitations, the literature has highlighted the impact, ranging from low to high levels of pain and disability, of chronic cervical MSC on individuals (1).

Further issues of epidemiology, prognosis and recourse, and the societal impact of chronic cervical pain have been observed. As mentioned earlier, the impact of cervical pain should be measured by its propensity to disable individuals and not by prevalence alone (4). One method of evaluating disability resulting from MSC is to evaluate its impact on work and participation. Cervical MSC symptomatology has been shown to influence work attendance and productivity, and subsequently has an economic impact (5-8).

Natvig et al (14) compared the self-reporting of pain at multiple sites of the body to levels of disability, functional capacity and work ability. The investigators looked at “*widespread*” reported areas of pain, other than the “*isolated*” or “*regional*” chronic cervical areas. Their results were comparable to previous findings (79-81), namely that a proportional reduction in function was observed to correlate to self-reporting of multiple pain sites (odds ratio (OR) = 5.13, CI 95%). The ratio of functional reduction to number of pain sites was equal for males and females. However, area of symptoms alone did not account for reduced productivity (8). Therefore, exploration of additional potential influences on loss of productivity and function within the workplace is deemed necessary.

However, limitations appear to exist in the literature on spinal MSC both in and out of the workplace, due to the lack of homogeneity in outcome measures. According to Hagberg et al (8), the high variability of office measures used, such as “*symptoms*”, “*sick leave days*”, or “*self-reported reduced productivity*”, has created the potential for varying point prevalence estimates of cervical MSC in sedentary occupations using computers. In addition, lack of homogeneity in outcome impairment measures may also limit information on the contributory, risk or prognostic factors toward chronic cervical pain such as occupation, perception of pain and disability, gender, and various psychosocial and pathophysiological aspects (8).

The relationship between descriptors of symptoms (such as severity and duration of pain) and self-reported reduced productivity in office workers has been explored. The level of severity and duration of cervical symptoms appear to influence the level of cervical impairment and disability (8).

Ylinen et al (82) used a sample of female clerical employees to reveal the high variability in individual impairment presentation noted in their office workers. The investigators looked at impairment-disability associations between the impairment variables of range of motion and maximal isometric cervical flexor and extensor strength, and the Neck Disability Index (NDI) (83,84). The associations between level of perceived NDI and range of motion or maximal strength testing were insignificant, whereas the associations between current pain and the variables of range of motion and maximal strength were strong.

These findings revealed the larger role played by neurologically-influenced pain inhibition on impairment, compared to the smaller influences of perceived symptoms of chronic pain and disability upon impairment. However, a limitation to the study was the lack of a control group. Psychophysiological cognitive influences have been observed in controls during human experimental studies (85,86). Consequently, without the existence of a control group, the study by Ylinen et al (82) could not exclude the potential for “*normal*” psychophysiological influences on study results.

Similarly, Hermann and Reese (87) and Chiu et al (61) found weak correlations between impairment variables in general and disability. However, they did find a significant positive correlation between the perceived severity of pain, in particular, and perceived degree of disability in patients with chronic cervical pain. In Hermann and Reese’s study (87), the correlation between intensity of pain and perceived degree of disability was not found to be influenced by time since onset of pain, according to their three groups of acute, subacute, and chronic patient groups. In contrast, Chiu et al’s study (61) found that the correlation between intensity of pain and perceived degree of disability did indeed increase with chronicity. However, the latter provided additional information on physiotherapy treatment and recorded patient satisfaction. Both the studies by Hermann and Reese (87) and Chiu et al (61) used mixed gender, hospital patient samples and did not specify occupation-type, making interpretation and generalisation of data difficult. This implies that factors of gender or ergonomics, and even psychological input produced by treatment, may have influenced each of the study results (87).

In general, a higher number of females than males in the workplace report cervical and upper quadrant symptoms (8). Similar findings have been reported in recent SA studies (2,40,41). Gender differences in prevalence may be based on females’ higher interest in and self-reporting of their health issues and musculoskeletal conditions (3). Further, true physiological gender-specific variations in pain perception have been discovered between males and females, and may play a role in the higher prevalence of cervical conditions in females (88,89). Gender and pain will be discussed in more detail in the section on Gender (p. 18).

The pathophysiological mechanisms of chronic cervical pain remain unclear (3,75,76). This is of concern, especially in light of the issues of epidemiology, prognosis and recourse, and societal impact of chronic cervical pain. The aetiology of chronic cervical MSC will now be discussed.

2.2.2 Aetiology of chronic cervical MSC

The multifactorial aetiology of chronic cervical MSC is discussed below. While each of these factors is discussed separately, complex relationships exist. Although the weight of each factor's specific contribution to the chronic pain condition is unclear, the biopsychosocial model allows understanding of the cumulative effect (41,54,90). Recognised risk factors for cervical MSC include age, gender and genetics. Further risk factors for chronic cervical MSC include posture and occupational activities, trauma, and health factors such as body mass index (BMI) and a lack of leisure activities. Risk factors for chronic cervical MSC will now be discussed further.

i. Age

Age-related degenerative changes to the lumbar and cervical spine appear prevalent in the third to sixth decade of life as a consequence of load and anatomical changes (3,91-94). Yet the effects of degeneration (and therefore age) are controversial (1). In a study by Nykanen et al (92), degenerative changes were closely associated with cervical pain and disability outcomes. However on closer inspection, degenerative changes did not correlate to reduction in measures of function (isometric strength and passive range of motion). The results of this study need to be interpreted with caution, as sample bias may have influenced the findings. The investigators used a fairly narrow inclusion category for age (25 to 53 years) for purposes of detection of degenerative changes. Furthermore, as female participants were recruited from a rehabilitative institution, it may have been expected that pain and disability were the measures worst affected.

Further aspects in the controversy surrounding age, degeneration, and level of spinal pain and disability, is the likely factor of under-reporting of spinal disorders and pain. The influences of under-reporting appear to occur in the elderly after the fifth or sixth decade of life (3), likely due to impaired cognitive ability, reduced level of function required at that age, or psychosocial stigma associated with the presence of pain and disability (3). With this in mind, the prevalence of cervical pain appears to decrease over the age of 50 years, and the prevalence of lower back pain decreases over 80 years of age (3). Therefore, the controversies remain unsettled as to whether common degenerative changes correlate with, or act as risk factors for cervical pain (1).

ii. Gender

As mentioned earlier, there is a higher prevalence in females than in males of cervical and upper quadrant symptoms reported within the workplace (2,8,40,41). This gender-specific pattern of prevalence is found in chronic MSC in general (3,8).

The complexities of the pathophysiology of chronic pain appear to be influenced by gender (95,96). Recent research has revealed the physiological role of genetically-defined (97) and gender-influenced pain perception (95). Gender variations in CNS pain processing are reported in both experimental animal and human pain studies (88,89,98). An experimental animal pain study that differentiated for gender revealed that female rats had an increase in glutamate-evoked afferent fibre activity of the masseter muscle compared to male rats. This gender difference appeared to be isolated to differences in magnitude of afferent fibre activity, and not to factors of mechanical threshold or mechanical sensitisation (98). Therefore a gender based approach to physiological differences in pain mechanisms can be used in individualisation of pharmacotherapy for analgesic responses (97), and a gender based approach should be used in the study of pain and chronic pain.

Gender differences in experimental animal pain studies on rats appear similar to those of human clinical and experimental populations (88,89,99). Pressure pain threshold has become a useful measure in human experimental and clinical studies for detecting central hyperexcitability, or a lack of sufficient pain inhibition (96). Two corresponding studies by Ge and colleagues (88,89) used pressure pain threshold levels to compare CNS pain processing mechanisms in human female and male participants. The investigators observed that following hypertonic saline injection into the upper trapezius muscle (UT), there was a greater sensitivity to pressure (low pressure pain threshold) in the adult females compared to the males. This appeared to be due to facilitation of spinal cord temporal summation in the females. In contrast, the male participants showed augmented CNS descending inhibitory activity, possibly contributing toward a lowered pain experience (88,89,96). These studies indicate that nociceptive and pain processing mechanisms differ in males and females, and reinforce the need to adopt a gender based approach in pain studies.

iii. Genetics

The complexities of chronic pain pathophysiology appear further affected by genetic predisposition (97,100). Family studies have shed some light on the mechanisms behind chronic pain, especially chronic widespread pain such as in fibromyalgia, inflammatory bowel syndrome, neurogenic pain and migraine headache (101,102). Complex investigations into sodium channels and gene cytokine expression have led to an increased understanding of the mechanisms behind genetic predisposition toward or protection against these specific types of chronic pain (101,102). Further, there appears to be a genetically based biological link shared by medical and psychiatric disorders that may influence pain sensitivity. The precise details, whether due to the extent of hypothalamic-pituitary-adrenal axis dysfunction, or the presence of variants of catechol-O-methyltransferase enzyme, are beyond the scope of this review (97,100).

iv. Posture

The head is supported and stabilised by neurological regulation of the upper cervical mechanoreceptors and muscular action of the small and larger dorsal muscles of the cervical spine, assisted by the vestibular and visual systems (103,104). However, there is disagreement as to whether head and cervical posture acts as a contributory factor to chronic cervical pain (75). Uncertainty remains in the association between posture and chronic cervical MSC, mainly due to poor quality of research methodologies used in most of the chronic cervical MSC studies (75).

A physiotherapy study by Yip et al (7) compared craniovertebral angles (CV) to the level of chronic cervical pain and disability in a case group of 62 participants and 52 controls. Their results showed a moderate correlation between these three variables, indicating that a fairly small, though significant 10% to 15% of total cervical pain and associated disability could be attributed to cervical posture. Strengths of the study by Yip et al (7) were the placing of strict exclusion criteria of any history of TMD dysfunction, as a contributory factor, on its case and control sample groups.

Methodological weaknesses lay in the lack of blinding of the investigators as to group category, despite there being good intra-rater reliability to measure CV angles. The investigators found that greater forward head postures (reduced CV angle) correlated with greater cervical disability, although they alluded to factors other than posture that may have been attributable to pain and disability.

Conversely, studies exist that have shown no difference in habitual sitting posture in those with and without postural cervical pain (75,76,105). Postural cervical pain was defined by Edmonston et al (75) as "*pain that is aggravated by sustained postural loading and relieved by postural modification*". In two groups of 21 symptomatic and 22 asymptomatic chronic cervical pain sufferers (age- and gender-matched), Edmonston and colleagues explored the contributory influences of "*habitual sitting posture*", "*perceived good posture*" and "*posture repositioning error*", using the validated Fastrak electromagnetic tracking method. No significant differences in postural variables of habitual sitting posture and posture repositioning error were identified between the case and control groups. There was a significant difference between groups for perception of good posture.

Participants in the case group perceived the correct posture to be that of greater head and neck forward tilt. A study limitation, possibly based on the small sample size, was the reduced number of outcome measures used for the subject topic of chronic postural cervical pain. For instance, measures of total daily or weekly frequency of time spent with office-based work, levels of pain and disability, and psychosocial factors were not considered within or between groups. In addition, the study was one of many that chose to utilise postural angles for comparison that did not include the CV angle (106). This creates difficulty for direct comparisons with other studies (7,76,107).

A recent study by Lau et al (107) compared the validity of the CV angle in relation to another postural angle. The investigators employed a similar sagittal posture measure to the CV angle, namely that of the upper thoracic angle, to explore relationships between posture and cervical pain and disability. The upper thoracic angle was measured as an angle between the horizontal line and a line drawn between the seventh cervical spinous process and the seventh thoracic spinous process. The findings of Lau et al (107) found the upper thoracic angle was a stronger predictor of postural cervical pain than CV angle measures. The OR provided an estimation of the number of times the risk of postural cervical pain increased for a single subject in the presence of increased upper thoracic angle measurements. The OR for upper thoracic angle was recorded as 1.37 ($p < 0.01$).

It has been inferred that the lack of homogeneity in sample selection in relation to age, gender, occupation, psychosocial characteristics and cervical pain and impairment characteristics, may have led to the controversy surrounding cervical posture as a contributory factor to chronic cervical pain (75). This was confirmed by a systematic review by Gadotti et al (108), who attempted, but failed, to establish the role of cervical musculoskeletal impairments including cervical posture as a risk factor for cervicogenic headache. To further confirm the lack of unanimity that appears to exist in most of the chronic cervical MSC studies on posture, reference is made to a systematic review by Olivo et al (13). Citing the poor methodological quality of many studies, their findings cast doubt upon any associations between head and cervical posture and TMD.

The authors suggested better controlled studies using larger sample sizes, comprehensive inclusion criteria, as well as an increase in the number of objective measures for posture. The same would apply for evaluation of the actual role of posture in cervical MSC conditions.

v. Occupational activities

Numerous authors have reported sustained seated positions and repetitive work of more than 4 h/day as prognostic factors for cervical MSC in adults (6-8,57,109,110). Similarly, Smith et al (111) and Brink et al (76) found computing of more than 8.5 h/wk to be the largest predictor for cervical MSC among adolescents. In all these studies, muscle fatigue is identified as the main contributing factor.

Muscle fatigue has been described as an inability to maintain a muscle's required force or contraction intensity (109). All muscle contractions are evident as resting contractions, submaximal or maximal contractions. A maximal voluntary contraction (MVC) is a maximal contraction performed by a group of muscles being analysed in a known position determined by a researcher. The effort intensity used during activities of daily living is generally 20% to 50% of MVC (109,112).

Muscle contractions in sedentary occupations such as office workers are evident as resting or short duration submaximal contractions of 2% to 5% of a muscle's MVC (113). However, physical exposure, duration and repetitiveness of movement are thought to influence muscle contraction levels (109). Variables of static muscle load and decreased periods of electromyographic (EMG) amplitude-based motor variability (number of periods per minute when the load is over 1% of a muscle's MVC) are thought to be predictors for cervical and upper quadrant MSC within sedentary occupations (113). It is theorised that static/isometric muscle activation patterns at rest (less motor variability) are associated with an increase in tissue ischaemia and inflammation, resulting in metabolic related muscle pain (109,113,114).

As mentioned earlier, cause or effect mechanisms for cervical MSC and posture have not been fully ascertained (75). However, it appears that workplace ergonomic-related conditions including non-specific chronic cervical MSC are associated with changes in postural cervical muscle activity (65,109,112,115-120). It is theorised that individuals with cervical pain adopt a forward head posture (reduced CV angle) (7,107), especially when distracted (110). The smallest change in sagittal head position, whether due to pain or sustained computer usage, results in an increase in CE and UT anti-gravity activation (7,112,119,120). The augmentation of cervical joint load and posterior structural stress in the forward head posture is theorised to lead to MSC (5).

Further detail on the limited number of medium to high methodological quality studies on chronic cervical MSC in general was provided in a systematic review by Borghouts et al (71). The systematic review on chronic cervical MSC among office workers revealed poor diagnostic criteria for selection into chronic cervical groups. For instance, the authors mentioned the limited standardisation of inclusion criteria for chronic cervical MSC samples within the office. This lack of standardisation may have been, as mentioned earlier, due to the differences in definition of chronic pain used by researchers (43,44,53), or due to differences in the type of outcome measures used (47,58,60). Similarly, a systematic review by Waersted et al (6) confirmed the above-mentioned findings.

Differences in definition of chronic pain may be limiting broader evaluation of the pathophysiological mechanisms behind chronic pain, pain and disability and its co-morbidities. For instance, due to inter-related signs and symptoms reported in those with cervical MSC and TMD (17,18,21,26,31,34,37,38,103,121,122), it would be deemed necessary to differentiate between the two often co-morbid conditions. Therefore, strict inclusion criteria are important for selection into chronic cervical groups, as are strict exclusion criteria of TMD dysfunction.

In addition, due to the potential for widespread areas of influence in chronic pain and disability (14), there is the need for strict exclusion of TMD from chronic cervical studies. Yet, numerous chronic cervical pain studies in physiotherapy have not attempted to either include or exclude for TMD symptomatology (110,116,123-125).

The concept of “*widespread*” areas of influence will be discussed in the next section whilst the relationship between the cervical spine and TMD will be discussed further in Section 2.4 (p. 49).

In essence, it is unclear whether chronic cervical MSC relates to workplace ergonomic-related postures. Investigators have increased their focus on the EMG muscle activity patterns of static and task-specific sitting postures in an attempt to clarify the mechanisms behind risk factors for occupation-type MSC (110,116,119,120,125-127). Recent studies have investigated motor adaptations to acute and experimental muscle pain and discomfort, as well as motor strategies in chronic cervical MSC (109,128). These mechanisms are discussed below.

vi. Muscle activity

The presence of pain or discomfort on muscle activity has been a topic of controversy (115). It appears the concept of motor control adaptation to nociception may not be fully predictable (129).

Surface EMG has played an important role in the assessment of muscle dysfunction in patients with chronic MSC (86,130). Elevated muscle-specific baseline tension has been considered an aetiological and perpetuating factor in chronic MSC, through its reflexive increases in muscle tension (85,86,130). However, additional aspects of sEMG evaluation that are considered potentially more important in the assessment of muscle dysfunction are attributes that reveal the actual extent of the muscle tension. These attributes include sEMG aspects of asymmetry of tension, symptom-specific reactivity to psychophysiological stressors, delayed return-to-baseline levels, and variations in firing patterns during dynamic movement (85,86,109,110,116-118,126,131,132). This additional sEMG evaluation has assisted in assessing the presence and extent of chronic MSC; and whether the presentation is a local or generalised problem.

Experimental animal and human pain studies using EMG have revealed simple to more complex motor strategies following pain-induction application (30,32,36,109,133). Variations in EMG data in current pain models have been explained by differing sampling methodologies, namely animal (32,36) or human experimental (30,126,133,134) or clinical pain models (109).

Animal experimental pain studies on rats have found simple relationships between nociception from the temporomandibular joint and facilitation of the muscle spindle system. The simple reaction to nociceptive input appears to be consequent hyperactivity in the agonist, antagonist and synergist of the jaw and cervical muscles at rest (32,36). This will be discussed further in Section 2.4.2 (p. 50). In contrast, human experimental and clinical pain studies, discussed below, have noted a more complex reorganization of motor strategies, which appear as graduations of motor changes in relation to chronological pain stages (109,110,116-118,126,135).

A human experimental pain study by Falla et al (126) observed that in the presence of acute pain induced in the sternocleidomastoid (SCM) and splenius capitis muscles, motor control strategies possessed a seemingly efficient and effective dynamic strategy, as previously documented (9,109,126,132). Excitation of nociceptive afferents created short-term inhibitory and reorganizational (plasticity) responses of the agonist muscle fibres, resulting in a protective decrease in activity in the painful muscle, both in terms of force and fatigue. In addition, there was a reorganization of synergist and antagonist activation, apparently for reasons of redistribution of load. This seems to occur for the motor output to remain unchanged despite the painful condition to avoid the disruption of a task. The entire motor strategy or change in muscular co-ordination appears to be task-dependent. However, of noteworthiness was the absence of increase in resting sEMG observed in the agonist muscle of the above-mentioned studies (109,126). The absence of an increase in resting sEMG with nociception confirms that the motor control adaptation to pain does not follow a simple linear relationship in humans. In general, following first episode pain, continuous motor impairments have been observed in human clinical pain studies in participants with chronic MSC.

Flor and Turk (85,131) and De Sade (86) looked at motor strategies presenting with chronic MSC, particularly in MSC-specific sEMG reactivity in those with chronic lower back pain, tension headache and TMD. They recorded elevated resting levels in the paravertebrals, splenius capitis and UT, the masseter and the temporalis. Their results revealed an asymmetry of tension, even in healthy participants, and variations in firing patterns during dynamic movement. Further, there were delayed MSC-specific return-to-baseline levels reported in those with chronic lower back pain (136), tension headache (86,116) and TMD (86,137,138).

In addition, increases in MSC-specific muscle activity during physical stressors and personally-relevant psychological stressors have been observed (137). Further, De Sade (86) revealed that both case and control groups responded with similar presentations of MSC-specific sEMG motor strategies during psychophysiological stressors in the clinical setting. Their control group displayed a fair degree of asymmetrically located, elevated baseline muscle tension of the masseter, UT, erector spinae, and biceps.

However, the data from De Sade (86) needs to be interpreted with caution, as it has not to date been published in a peer-reviewed journal. In addition to MSC-specific motor adaptations, autonomic and cortical brain function changes have been reported in MSC-specific groups (56,85,86,131,139) and in controls (86) during clinical settings. These investigators concluded that methodological limitations of chronic pain studies may arise due to the inability to control central changes in clinical settings. Consequently, they highlighted the ongoing uncertainty as to whether motor changes elicit, maintain, or are even associated with chronic MSC pain (56,85,86,131,139). However, advances in technology on autonomic and cortical changes are beyond the scope of this review.

Investigations focussing on chronic cervical MSC in isolation have studied the complex reorganization of motor strategies. Some of these strategies include altered strength, reduced endurance and recruitment strategies of the cervical agonists, synergists and antagonists (109,118,140-142). These “*inefficient*” patterns of muscle activation are thought to play a role in the initiation, perpetuation, or recurrence of cervical pain and disability.

Specifically, patients with chronic cervical pain have presented with inhibition of the deep cervical flexor muscles of longus colli and longus capitis, evident during the craniocervical flexion test (117). Further, there are reports of a more static muscle activation pattern at rest (less motor variability), and a decrease in the ratio of both cervical flexor and extensor strength to unit body weight in those with chronic cervical MSC (109,128,129,143). Of increasing clinical value, however, are the findings by Falla et al (140), who observed that the reported neuromuscular inefficiencies were most evident at low loads of MVC (less than 25% MVC). As mentioned earlier, the effort intensity during activities of daily living is generally 20% to 50% of MVC (109,112), and during sedentary sitting activities is generally 2% to 5% of a muscle's MVC (113). Therefore, neuromuscular inefficiencies may be displayed in office workers with chronic cervical MSC, thereby compounding their condition.

Additional patterns of neuromuscular inefficiency in chronic cervical MSC have been observed during functional low load, upper limb tasks. An increase in the recruitment of cervical antagonists and synergists is seen in response to a reduction in agonist contractile capacity (110,116,117). Falla et al (116) used a mixed gender, right hand dominant, case-control sample of 20 chronic cervical participants (made of whiplash and idiopathic cervical pain participants) and 10 controls to investigate MSC-related sEMG activity levels during an experimental repetitive upper limb task at a desk. The case group showed elevated sEMG levels in the bilateral SCM and anterior scalene muscles, and unilaterally in the UT. The right UT muscle in the case group showed lower sEMG amplitudes, displaying protective lower sEMG amplitudes. This lowered UT sEMG activity was potentially due to its agonist role in the right hand dominant task. In addition, during the 10 second post-exercise period, a reduced ability to relax was evident in all of the agonist, antagonist and synergist muscle groups in the case group. Limitations to the study were the lack of detail on location of pain whether bilateral, left- or right-sided symptoms were reported. This is noteworthy as stronger associations between ipsilateral side of pain and an increase in sEMG dysfunction, versus hand dominance and expected sEMG increases, have been discovered in studies on chronic cervical MSC (110,144).

Further neuromuscular inefficiencies have been reported between the cervical synergists of UT and CE in chronic cervical MSC (110,125). Under normal circumstances, the UT and superficial CE muscles of splenius capitis and splenius cervicis play a role in postural control during static postures (103,104). Szeto et al (110) investigated the effects of sedentary sitting with monotonous keyboard tasks using sEMG in symptomatic and asymptomatic female office workers. The procedure included five trials of 60-s periods during a one hour typing session.

Results revealed an increase in sEMG activity in the ipsilateral UT of those with pain, with an associated reduction in activity in the ipsilateral CE. In contrast, there was symmetrical lowering of the sEMG activity in the UT in the control group, with higher levels of CE on the dominant hand side. Further results showed that over the length of experimental time period, higher levels of discomfort in the case group occurred, leading to additional increases in UT muscle activity.

Therefore, the high amplitude ratios of UT/CE seen in high discomfort groups, compared to low discomfort groups or controls, depicts the altered recruitment patterns in cervical synergists in the presence of chronic pain. Of interest would have been an observation of the patterns of activation of the UT and CE during these monotonous postural tasks. In addition, a study limitation was the lack of information on any other contributory factors to the sEMG changes seen in the chronic pain group, such as intrinsic physical features or anxiety and other psychological variables.

Further, Szeto et al (125) observed that the altered recruitment patterns in the UT and CE seen in symptomatic female office workers were not habitually adopted as a generalised manifestation of the pain disorder. Rather, these altered recruitment patterns were present in task-specific postures (such as actual typing versus hands on lap). These findings point toward a combination of physiological feed-forward motor control mechanisms and a psychologic-related anticipatory task demand, both in response to the presence of chronic pain (125). These findings were confirmed by Johnston and colleagues (86,120), who found that the increases in muscle activity of the cervical flexors and extensors and delayed relaxation of the UT and CE occur in both the presence of chronic pain and in task-specific activities. The investigators stressed the importance of using non-workers as true controls when revealing relationships between chronic pain and altered motor activity.

Therefore, it appears that various forms of psychophysiological dysfunction act as a response or perpetuating factor (rather than a risk factor) to chronic cervical MSC within the workplace (6,120,125). This will be further discussed in the section titled Catastrophisation, anxiety, depression and mental load (p. 36).

Galiano-Castillo et al (144) were interested in cervical motor control strategies specifically relating to altered patterns of activation. Their case-control cohort study used breast cancer survivors with a chronic presentation of post-operative cervical MSC. The investigators used a linear model of repeated analysis of variance measures (ANOVA) for sEMG amplitude over time, namely at baseline, 10-, 60- and 120-s epochs. Results showed similar neuromuscular inefficiencies and augmentations in SCM and UT activity during a repetitive functional low load upper limb task to those previously reported (86,116). Further, Helgadottir et al (145) used repeated measures to analyse the altered pattern of recruitment that may occur in the force couples of serratus anterior and trapezius (upper, mid, and lower) in those with chronic cervical MSC. A delay in onset of activation was isolated to the serratus anterior muscle, with no significant differences between groups in the pattern of activity in the trapezius muscle. The reason for this may have been due to the great variability in CSD onset observed within each group, exacerbated by the small sample size (idiopathic cervical group: n = 22; whiplash-associated group: n = 27; control group: n = 23).

All changes in motor control strategies are theorised to be due to central mechanisms (82,109,126,144). As seen above, sEMG assessment of muscle strategies and firing patterns in the cervical agonists, antagonists and synergists has assisted in revealing the extent of muscle tension. Furthermore, the extent of muscle tension has in turn assisted in identifying whether the presentation of chronic MSC is a local or a generalised dysfunction (9,109,118,132,140,142,146). As mentioned earlier in the section on Occupational activities (p. 22), significant acknowledgement has been given recently to the role of widespread areas of pain as a potential contributory factor (through onset, perpetuation or recurrence) to chronic cervical pain and disability (14). In so doing, effective approaches to assessment, management and outcomes to chronic cervical MSC are addressed (109,118,140,142,146).

Further, co-existence of chronic cervical MSC and TMD has been established. Yet the mechanisms behind this relationship remain unclear (13,15,17-23). By deduction, investigations into the potential muscle dysfunction that extends from the cervical musculature to encompass the temporomandibular musculature may seem beneficial in those with chronic cervical MSC. To the best of our knowledge, there remains a paucity of information in this regard. The current proposed relationships between the cervical and temporomandibular areas will be discussed further in Section 2.4 (p. 49).

vii. Trauma

Various intrinsic and extrinsic risk factors for the development of chronic cervical MSC have been discussed above. In addition to these, motor vehicle trauma is a large contributory factor toward chronic cervical MSC (64,90,147-149). Furthermore, the presence of trauma versus insidious onset of chronic cervical MSC may have an influence on measures of cervical pain, through varying biopsychosocial mechanisms.

A number of studies have alluded to the presence of different pathophysiological processes existing within chronic cervical pain (64,148). Studies that directly compare traumatic vehicle WAD and non-traumatic chronic cervical pain samples are of interest, as both types fall under the umbrella term CSD. As mentioned earlier, subgroups that create homogeneity within the broad category of CSD and non-specific chronic cervical pain are useful for treatment and management purposes (1,71,73,74).

Elliot et al (148) compared the relative cross-sectional area (rCSA) of the deep and superficial CE muscles in age- and BMI-matched adult females with either a WAD or non-traumatic cervical pain history. Measures of muscle size and rCSA have been used for the assessment of motor changes and outcome measures for rehabilitation in cervical disorders (128,147). Despite a shorter duration of chronicity reported in the WAD group, there were higher disability scores and higher levels of distress observed in this group compared to the non-traumatic cervical group. In addition, there were with far lower muscle:fat ratios probably due to an increase in widespread fatty infiltrates seen in the deep layer of the CE muscles. All of the above findings appear to relate to different pathophysiological processes observed in WAD and non-traumatic chronic cervical pain.

Investigators have noted further variations of pathophysiological processes existing within the broader picture of chronic cervical pain. Sterling et al (149), Sterling and Pedler (150), and Chien and Sterling (64) observed possible variations in CNS processing of peripheral noxious inputs in those with WAD and non-traumatic cervical disorders, and even within-group WAD variations. To elaborate, individuals with WAD and those with chronic non-traumatic cervical pain have presented with shared similarities as well as distinct differences in sensory signs and symptoms. Some similarities were lowered nociceptor thresholds (resulting in increased A δ and C fibre firing) and heat receptor thresholds (increased C fibre firing) in local areas and in areas far removed from the pain site (64). The WAD group also had augmented signs of widely disseminated pain, with lowered cold receptor thresholds, raised vibration thresholds and raised light touch/hypoaesthesia thresholds, which were not present in the non-traumatic chronic group. Possible reasons proposed for this variation in CNS between the two groups include differences in pain duration (persistence versus episodic), pain severity, and perceived disability. From these data, it appears that those with WAD chronic cervical MSC have greater CNS sensitisation.

Similarly, Falla et al (116) observed that perceived level of cervical disability had a stronger association with elevated cervical sEMG activity levels at baseline, during and post-task in those with WAD compared to idiopathic cervical participants or controls. Once again, investigators highlighted the varying CNS somatosensory disturbances observed in chronic cervical pain due to trauma, explained by altered central and peripheral pain processing mechanisms (64,148). Therefore the investigators concluded that the presence of trauma contributes to the development of chronic cervical pain. However, a study limitation was the lack of information on any other contributory factors to chronic cervical pain, such as intrinsic joint pathology, anxiety or psychological variables.

In a cross-sectional study limited to females aged 18 to 45 in the USA, a comparison was made between 79 WAD participants and 34 healthy controls (147). The case group's inclusion criteria specified the need for a three-month to three-year persistence of whiplash-related pain and disability, which remained untreated. Magnetic resonance imaging results showed that in the WAD there was an increase in rCSA of the multifidi due to higher fatty infiltrate, and a decrease in rCSA of the more superficial CE musculature. The study concluded that morphometric changes in the rCSA of the posterior cervical musculature did indeed occur following trauma. Surprisingly, neither the duration of symptoms nor self-reported levels of pain and disability correlated with rCSA. Detection biases may have influenced the results, as there was lack of blinding of the examiner as to the status of the participants, although an inter-examiner reliability test was performed on five participants. Further, as it was not a longitudinal study, it could not be ascertained at what point these morphometric changes occurred post-traumatically. Therefore, the reference data on muscle morphometry diagnostic testing appears to lack clinical value with regards to chronicity and chronic pain and disability.

As mentioned above, variables of chronicity or duration of symptoms and self-reported levels of pain and disability do not appear to correlate to rCSA (147). In essence, the pathophysiological processes associated with chronic cervical pain do not appear to be isolated to simple mechanisms of injury.

Rather, to increase knowledge on the multidimensional nature of chronic pain (and its chronic forms of presentation or co-morbidity) the recommended shift is toward the pathophysiological biopsychosocial mechanisms behind the maintenance - rather than simply the cause - of chronic pain (15,47,58). Further biopsychosocial risk factors for the development of chronic cervical MSC will now be discussed.

viii. Health factors

Health factors that may act as risk factors to chronic cervical MSC include increased body mass, lack of leisure-related physical activity, and low perceived health status and HRQoL. Increased body fat percentage has been found to correlate with lower back pain, significantly so with the BMI greater than 30kg/m² (151). Chronic cervical pain sufferers have significantly greater BMI than healthy controls (128,148). However, investigators using anthropometric characteristics such as ultrasonography have been unable to establish the cause and effect mechanisms of these relationships, as most studies are cross-sectional in design (128,148). Therefore, it cannot be assumed that an increase in BMI is predictive of chronic cervical MSC.

There are well recognized benefits of intensity- or frequency-related physical activity for reasons of leisure, to aspects of emotional health, cardiovascular health, and reduction in mortality (151-153). Furthermore, physical activity levels and its association with chronic MSC prevention have been observed.

A Norwegian longitudinal study compared frequency of leisure-related physical activity to incidences of isolated and widespread MSC complaints of the lumbar, cervical, and upper limb areas (154). They reported results at baseline and at 11 years. Their findings indicated that those who exercised at baseline (at varying levels of frequency and intensity) were less likely to report chronic MSC, and particularly chronic widespread pain, compared to inactive individuals. To elaborate, frequency levels of one to three exercise activities per week reduced the likelihood of developing complaints of chronic widespread MSC 11 years later by 20% to 28%. Similarly, intensity levels of a consistent and moderate level were associated with a greater than 50% decreased prevalence of chronic widespread MSCs 11 years later.

However, possible limitations to the study may have existed in the form of sample bias. The sample that responded to the study's questionnaire was predominantly females of high socio-economic status, limiting generalisability of the results.

In addition, the positive influences of leisure-related physical activity on recovery from work-related MSC and early recovery from WAD have been recorded (1,155). A longitudinal study by Goldman (155) looked at the effects of pre-injury physical fitness levels on recovery rate following whiplash-related cervical pain and disability, at nil months, three months and six months post-injury. Their results were two-fold. Firstly, they showed that no amount of pre-injury physical fitness had any beneficial effect at time of injury. Secondly, the benefits of pre-injury physical fitness were isolated to those involved in medium to high levels of recreational exercise. The benefits seen were a reduction in cervical pain and disability, and an improvement in work attendance at three months and six months post-injury. The investigators concluded that the rewards of recreational exercise did not appear to be preventative or immediate, but that the transition from acute to chronic phases of pain-related cervical disability post-injury could be substantially reduced or prevented through exercise. Therefore, it is pertinent to explore levels of physical activity in studies on the aetiology of chronic cervical MSC.

Increases in leisure-related physical activity have been linked to the beneficial effects on chronic MSC, as described above (153-155). In contrast, reductions in leisure-related sporting activity and social interaction have been linked with maladaptive pain-related disability (62,67). Without the healthy belief of the "*locus of control*", which arises from physical activity, an individual has been described as potentially curtailing their quality of life and centering life around pain (67), p. 255.

The positive influences of leisure-related sporting activity on cervical disorders have been discussed above. However, physical inactivity is considered a minor associative factor to the development of chronic MSC in comparison to the risk factor of low socio-economic environment for instance (3,40,48).

Yet, those of low socio-economic environments are predominantly of poorer health status and less physically active (156). Therefore, when considering absolute numbers of those suffering with chronic MSC, physical inactivity remains an influential risk factor (154).

Health status and perceived HRQoL represents one of the strongest influences on the development of MSC problems (2,3,12,40,46,59,157-159). The multidimensional construct of HRQoL, with mental, physical and social domains, has been used as both an indicator for MSC, as well as an outcome measure for rehabilitative success (41,47,160,161), for example, following cardiac surgery (162). A reduced HRQoL may often accompany higher states of psychological distress, anxiety and depression (15,163). It seems apparent across studies on health and disease that levels of depression act as one of the largest predictors of HRQoL and poor biological outcomes (2,3,15,46,59,157,162,163). However, the number of clinical variables that act to confound or influence HRQoL are difficult to measure and control. Hence specific causal relationships of health measures to MSC may not be established, only proposed (164).

ix. Catastrophisation, anxiety, depression and mental load

Studies using mixed gender groups, with exclusion criteria for other medical conditions, have found that those with chronic cervical disorders appear to have significantly greater impairments in HRQoL and higher states of anxiety, compared to controls (15,163). Three of the more potent individual constructs within psychological factors are “*pain catastrophising*”, “*pain anxiety*”, and “*anxiety sensitivity*” (58). Keogh et al (58) revealed these factors as playing different roles in contributing to chronic pain and disability. “*Pain catastrophising*” appeared to be the strongest predictor for current pain, due to rumination and worry. Secondly, “*pain anxiety*” was positively predictive of behaviour toward pain-related tasks, due to fear-avoidance. Lastly, “*anxiety sensitivity*” appeared to be an isolated anxiety disorder outside of the pain, which inversely predicted disability. Although the investigators studied patients with acute hand injuries, their results confirmed and elaborated upon the findings of several previous chronic pain studies using sample populations with either specified low back pain or unspecified spinal pain of the cervical, mid or lower back (2,47,160,161).

Further, pain catastrophising and the fear of physical movement and activity (kinesiophobia) have been identified as risk factors for the development of chronic cervical pain (47,160,161,165). Sullivan et al (70) used the pain catastrophising scale for the self-reporting of the negative perception of pain, through processes of rumination, magnification and helplessness. Interestingly, they revealed that coping strategies toward pain were used in both catastrophisers and non-catastrophisers. In the case of the catastrophisers, however, the use of coping strategies was not associated with pain reduction or effective distraction strategies for pain. Individuals who appear to have less effective coping strategies toward acute pain may, therefore, be predisposed toward chronic pain (47,160,161,165,166).

Confounders have served to only loosely associate mental disorders with spinal MSC (2,46). After adjusting for confounders such as age, gender, socio-economic status and other chronic pain or medical conditions, Smuts (2) observed that chronic spinal MSC within a South African context was significantly co-morbid with both anxiety and major depressive disorders (mood disorders). Further, the investigator determined that the association between MSC and general mental disorders was stronger in females compared to males. In contrast, the association between spinal MSC and post-traumatic stress disorders was particularly strong in males. The debate in literature persists as to whether depression is a likely predictor of MSC, rather than a response to the experience of pain. The former argument is most recognised (3,46,59,157,163). However, Smuts (2) speculated that depression was more likely to be related to disuse and disability, due to anxiety and fear-avoidance. Nevertheless, there is consensus that type of pain and circumstances leading to the development of chronic pain would most likely infer causality between mental disorders and spinal MSC (2).

Mental load within sedentary occupations may be a contributory factor related to chronic cervical MSC (6,110,120). As was previously mentioned in the sections on Occupational activities (p. 22) and Muscle activity (p. 24), there may be neuromuscular inefficiencies and altered muscle activity related to chronic cervical MSC and occupation, compounded by anticipatory task-specific postures, seen in female office workers (for biomechanical and non-biomechanical purposes) (6,110,120,125). These features appear to be both contributory and perpetuating factors to chronic cervical MSC.

Johnston et al (120) examined non-biomechanical muscle activity related to emotional load and mental load. The investigators explored psychological variables of female office worker strain, work stressors and job satisfaction. In addition, they looked at physically stressful conditions in task-specific positions. Though they found no significant association between the above-mentioned psychological measures of employee strain and NDI, they did detect an association between muscle activation patterns and stressful conditions in task-specific positions. Their findings are comparable to those by Szeto and colleagues (110,125). Johnston et al (120) reported increases in attention-related sEMG activity of the CE, SCM, and anterior scalene muscles in all pre-, during-, and post-task phases. These increases were evident in both symptomatic and asymptomatic cervical participants, which could predispose individuals to cervical pain and disability.

Further, Johnston et al (120) reported an increase in UT activity in the symptomatic cervical participants, yet this was only recorded post-task, and not during-task as per Szeto (125). Differences in results may have been due to variations in sampling methods used for the controls, thereby influencing sampling bias. Szeto (125) used occupation-matched asymptomatic controls, whereas Johnston et al (120) used non-workers as “true” controls. Although there may be unanimity regarding the presence of the human element of psychophysiological influences in chronic cervical MSC, the mechanism of their relationship with chronic cervical MSC remains unclear. Nevertheless, it appears that various forms of psychophysiological dysfunction act as risk factors for chronic cervical MSC (6,120,125).

x. Socio-economic status

There appears to be a significant problem in both developed (1,4,51) and developing countries with regards to the prevalence of spinal conditions and peripheral joint pain (3,40,49). Age- (3,91-94) and gender-based (2,8,40,41) contributory factors of chronic cervical pain were discussed earlier. Further, in developing countries specifically, there appears to be an increase in the severity, duration and recurrence of chronic spinal pain and disability, especially with low back and cervical/head pain, both with and without co-morbidity (3,40,49). Ehimario (48-50), on the basis of comprehensive surveys conducted in the Eastern Cape, South Africa, reported 38% to 74% point prevalence of chronic back and head pain, with pain severity scores of 5 to 8 (on a scale of 10). These findings highlight the nature and severity, and subsequent socio-economic burden of chronic pain in developing countries.

Possible mechanisms behind these associations may be related to health issues and level of education. Firstly, health risks such as obesity and smoking are more prevalent in lower socio-economic environments (3). Obesity and an increase in BMI are associated with chronic cervical MSC (128,147). However, it is difficult to determine cause and effect relationships (128,147). Similarly, smoking has been viewed as a further health risk to generalised chronic MSC (3,164). Yet its role has been ill-established due to the number of clinical variables such as psychosocial factors, which act to confound or influence health status, HRQoL, and MSC (3,164).

Secondly, a generally lower level of education associated with low socio-economic status may perpetuate MSC problems, especially in low back conditions (3). Pain misconceptions, fear beliefs, and poor adjustment to pain may initially influence deconditioning of muscle function at a body level, and thereafter continue to affect disability at an activity and social participatory level (55). Hence, level of education may act as a risk factor to chronic cervical MSC, through persistence and recurrence of spinal MSC (3).

Further, Hagen et al (156) examined the relationship between socio-economic status and type of MSC (156). The investigators revealed that in their mixed-gender survey on Norwegian adults, type of occupation and levels of income were used to draw associations between low socio-economic status and higher prevalences of MSC. In addition, they observed these associations to be particularly strong between low socio-economic status and areas of widespread pain not limited to isolated areas of MSC.

2.2.3 Cervical MSC disability and co-morbidity

To conclude this section, the known biopsychosocial factors associated with increased risk for chronic cervical MSC have been discussed. However, there is limited literature available on the relationship between chronic cervical MSC and co-morbidities (14,22,23,46). It is becoming increasingly apparent that the combination of chronic cervical MSC and co-morbidities has a much greater resultant disability than either condition alone (12,40).

The pathophysiological process of chronic pain has been ascribed to the maintenance of peripheral- and/or central sensitisation. The maintenance of central sensitisation is proposed as a consequence of ongoing nociceptive input from the periphery to the cortex (44,56,68,70). This appears to be the mechanism behind central sensitisation and its contribution both to the experience and maintenance of chronic cervical MSC (9,10). Therefore, links between the cervical spine and any structure that has biomechanical, neurophysiological and/or psychological relations may be regarded as a potential ongoing nociceptive input to the cervical area (13,15-18,21,22,29,167).

The mechanisms for chronic cervicogenic headache have recently been increased to include any structure that may produce nociceptive input to the trigemino-cervical nucleus linking the head and face (168). Further, physical links and influences between the cervical spine and ocular and vestibular systems have been identified through peripheral afferent nociceptive input (16). In addition, co-existence of signs and symptoms have been observed in chronic cervical MSC and TMD (19,20), as well as prevalence of both as co-morbid conditions (13,15-18,21,22,29,167).

Yet, the precise mechanisms for the co-existence of these two co-morbid conditions are not clearly understood (13,15-18,21,22,29,167). The epidemiology, aetiology and mechanisms of TMD will be presented to improve understanding of the association between cervical MSC and TMD.

2.3 Temporomandibular disorders

Temporomandibular disorders embrace a group of pathologies that affect the temporomandibular joint (TMJ), masticatory muscles and/or related structures in the head and cervical area (17,103,122). In some literature, the term TMD may be interchangeable with the term craniomandibular disorders (CMD) (122). TMD have been differentiated according to the Research Diagnostic Criteria for TMD (RDC/TMD) into three subgroups. These subgroups are: myogenous, intra-articular and a mixed group with both myogenous and arthrogenous components (122). Myogenous disorders of TMD account for almost half of all cases of TMD (122,169). The classical definition of the large myogenous subgroup of TMD, namely TMPDS, is:

“A syndrome that requires the presence of at least one of the symptoms of unilateral pain around the ear or pre-auricular area or near vicinity, pain when opening the mouth wide, and pain in the muscles of mastication of the mandible. There should be the absence of clinical or radiological changes in the TMJ itself” (122), p. 328.

This was first proposed by Laskin in 1969 (170).

Intra-articular disorders in TMD appear to be isolated to physical joint-related signs and symptoms, whereas the mixed subgroup presents with myogenous and arthrogenous pain-related disability and psychological conditions (122). The focus of the literature review is on TMD in general, as well as on the specific subgroup of TMPDS. There seem to be strong associations between the co-existence of cervical MSC and TMPDS (17,18,22,103). It is significant that the distinction in definition between TMD and TMPDS is unanimous; however consensus as to the precise mechanism behind each has not been reached.

2.3.1 Epidemiology of TMD

The lack of standardized diagnostic criteria for TMPDS has led to varied prevalence data (21). Nonetheless, the prevalence rate for TMPDS has been estimated at more than 20% of the general adult population in the US (171), in the UK (25), and in Europe (23). However, there is an absence of literature regarding the prevalence of TMPDS in South African adults.

In addition to the lack of standardized diagnostic criteria for TMPDS are reports on the common subjective and objective TMPDS features that are potentially prevalent in 8% to 45% of the general “*control*” community (presenting in any form of the description in italics above) (17,18,172). For example, Kalanzi (169) investigated the prevalence of adolescent temporomandibular dysfunction in South African adolescents. It was observed that of the 14 control and 61 case group participants with teeth malocclusion, 45.3% of the total sample (including controls), reported one or more symptoms of TMPDS.

The independent impact of TMPDS as a subgroup is unknown, yet the impact of TMD ranges from socio-economic burdens (due to absenteeism and medical consultation) to disruption of sleep, impairment in HRQoL (173), and avoidance of certain foods (46). Only one in five individuals with TMD is predicted to seek treatment for the condition (174). The following section describes the aetiology of TMD (21).

2.3.2 Aetiology of TMD

The contributory factors for TMD include age, gender and facial morphology. Furthermore, bruxism and psychosocial factors, as well as dysfunctions in the cervical spine and craniofacial areas act as factors contributing to TMD. These will now be discussed further.

i. Age

The literature establishing the prevalence of TMD relative to age makes various claims. According to Gremillion et al (171), the prevalence of TMD follows a Gaussian-type curve, with the average age of affected individuals being 33.9 years. Ciancaglini et al (23) argued that once TMD is broken down into its subgroups, the association between TMD and age appears clearer. The investigators observed that TMD prevalence, isolated to TMPDS, appeared to decrease with age, though not significantly. A possible reason given for the weak relationship between TMPDS and age was the simultaneous decrease in age-related prevalence of teeth clenching, a known contributing factor for TMPDS (137,138,175,176). In contrast, Armijo-Olivo et al (172) observed that TMD prevalence, isolated to arthrogenous cases, appeared to increase with age.

ii. Gender

The prevalence of TMD and TMPDS is more common in females (23,99). However, gender-correlation studies detecting a higher ratio of females versus males with TMD and TMPDS have struggled to explain the mechanisms for this variation (23,99). Clinically-based studies have alluded to gender differences based on hierarchical levels of chronic TMD and associated psychological factors, yet few associations were found (23,99). Instead, associations between females and their greater health awareness, interest in symptoms, and self-reporting of symptoms may have a strong influence on gender-based differences in TMD and TMPDS prevalence (99). Further, clinical studies have alluded to a greater prevalence of TMD and TMPDS in females due to the influences of associated bruxism (23,24,138).

More recent human experimental pain studies have supported data on gender differences in TMD and TMPDS prevalence (88,89). As discussed earlier in the section titled Gender (p. 18), human experimental pain induction in the UT muscle revealed the existence of gender influences in nociception (88,89).

iii. Facial morphology

Variations in mandibular divergence, a term used for morphology of the face, have been observed in both inter- and intra- ethnic population groups (26,31,177). Alcalde et al (177) compared the hard cephalometric and soft-tissue landmarks of a mixed gender Japanese sample of 217 adults to the original data from a white male population (178,179), in an attempt to gain normative data for gender and ethnic group. Significant differences in landmarks for gender and ethnic group were found (177). Resultant normative data per group may represent an aid for TMD diagnosis and possible orthodontic or surgical management.

Tecco et al (31) demonstrated an association between a “low” mandibular divergence (increased jaw retrusion) and an increase in sEMG activity of the masseter in the mandibular rest position (and of the CE and UT muscles). However, due to the cross-sectional study design, the investigators could not infer causal relationships of form or function in the development of TMPDS.

iv. Bruxism

Bruxism has been defined as overactivity of the masseter (and temporalis) muscles of the mandible (26-29,137,180-182). The masseter, consisting of deep and superficial layers, arises from the zygomatic processes and arches (cheek bone) and inserts into the lateral superior and inferior half of the ramus of the mandible (corner of the jaw). Masseter action includes mandibular elevation during mouth closure or chewing/mastication, and mandibular retrusion. Antagonists to the masseter are the anterior throat muscles of digastric, omohyoid, and hypoglossus muscles. Synergists to the masseter muscle are the contralateral masseter, the temporalis and the pterygoid muscles. Innervation is via the masseteric aspect of the trigeminal nerve (cranial nerve V) (103,130).

A longitudinal study on TMPDS and bruxism in young adults reported a significant association between these variables (25). This UK study, consisting of 337 participants aged between 30 to 31 years, is currently the largest longitudinal study (20 year follow-up) on TMPDS in young adults. An epidemiological survey was conducted on 520 families selected at random from a town census list in a metropolitan area of Italy (23). The population sample constituted a wide range of the adult population (18 to 75 years of age). The overall prevalence of bruxism was reported at 31.4%. There was no significant difference (at $p > 0.05$) between females and men for prevalence of bruxism. A study done on the white population of Oranjemund in southern Africa reported that 11 of 100 participants (greater than 10%) of the total sample displayed bruxism as a parafunctional activity (183). However, their prevalence figures on bruxism cannot be extrapolated to the entire SA population, as their sampling method was one of convenience. Participants were recruited from a sample population of medical referrals that were seeking treatment for TMPDS.

Bruxism commonly presents in the form of daytime teeth clenching or nocturnal teeth grinding activities, in isolation or combination (23,24). Nocturnal teeth grinding has received more research scrutiny compared to daytime clenching, and potentially has clearer clinical signs (24,25). Measures of teeth abrasion have recently been considered as poor tools for characterising nocturnal teeth grinding prevalence, with weak validity and reliability (24,25).

The weakness of this tool appears to be two-fold. Firstly, causes of teeth abrasion may be undifferentiable between incidences of teeth malocclusion versus incidences of chemical attrition seen in cases of bulimia (24). Secondly, clinician-observed teeth abrasion may bias toward patient self-reporting of nocturnal teeth grinding tendencies (24). These findings are coupled with recent investigations confirming that no significant correlation between tooth abrasion, self-reporting of nocturnal teeth grinding, and TMPDS exist (24,25). Therefore, the validity and reliability of recognising “*true*” prevalence of nocturnal teeth grinding remains questionable (24,25).

A more valid, reliable tool used for bruxism appears to be in the form of subjective recollection of an individual's daytime teeth clenching parafunctional habits, through the use of standardised questionnaires (122,184-188). Daytime clenching and nocturnal clenching differ in their stages of consciousness, with nocturnal bruxism believed to be a stress-related sleep disorder, having a stronger genetic predisposition than daytime clenching mechanisms (24,25,189). Therefore, pathophysiological mechanisms and management tend to differ between the two components of bruxism (24,25).

Experimental studies have investigated the effect of teeth clenching on TMPDS (26-29,137,180-182). Clinically, engaging in parafunctional teeth clenching for 20 minutes daily over a five day period was shown to be sufficient to cause signs and symptoms of TMPDS (137,138,175,176). However, not all incidences of bruxism and masseter overactivity have been associated with malocclusion or TMPDS (23,24,138). For instance, in the large epidemiological study done by Ciancaglini et al (23) (discussed earlier on p. 43), as many as 15% to 25% of the total sample of bruxers (n = 152) did not report local masticatory pain. In addition, the balance of bruxers reported orofacial (21.2%) and cervical pain (37.2%). Possible mechanisms for pain in these areas may have been due to local muscle nociceptor activity, as well as prolonged nociceptive excitability of the masticatory muscles with resultant sensitisation of afferent nociceptors (23).

In essence, bruxism has been identified as a complex predisposing, triggering or perpetuating factor to masticatory dysfunction and TMPDS (21,23-25). Ciancaglini et al (23) reported that the presence of bruxism had a fairly high specificity rating of 74.5% and a low sensitivity rating of 43.5% for TMPDS. An absence of TMPDS and masticatory dysfunction was therefore likely to be accompanied by a lack of bruxism. However, a lower likelihood occurred that individuals with diagnosed TMPDS were involved with bruxism. As mentioned earlier, 8% to 45% of the general "control" community have been shown to present with subjective and objective TMPDS features.

v. Changes in joint mechanics

Malocclusion of teeth may directly result in TMD through stresses on the TMJ, or indirectly through dynamic joint mechanics. Local facial trauma or WAD, loss of posterior teeth contact, lateral deviation of the mandible, prominent or missing incisors, removal of more than one tooth (excluding third molars) per quadrant (28,180), partial or total anterior cross-bite, general anterior or midline spacing, or severe anterior crowding and a deep overbite, may result in changes in joint mechanics (21,25). These changes in joint mechanics cause increased stress on the TMJ disk and ligaments (21,25).

In addition, malocclusion of teeth may result in differences in position or rotation of bilateral TMJs, influencing changes in the muscular force axes acting in the surrounding area (103,122). One of the major force generators in the surrounding area is the masseter muscle. Under normal circumstances, the masseter muscles are relaxed, however the resultant tension on them created by occlusal disharmony may stimulate bruxism. Subsequently, there may be dynamic premature anterior teeth contact, leading to mandibular dysfunction and/or TMPDS (26,31,34,37,38,121).

vi. Catastrophisation, anxiety, depression and mental load

People reporting TMPDS exhibit significantly higher degrees of neuroticism and trait anxiety than those without TMPDS (15). Pallegama et al (15) used matched mixed-gender groups of isolated TMPDS, combined TMPDS and cervical spine disorders, and controls to compare physical and psychological characteristics. Those with combined TMPDS and cervical disorders reported being the most physically and psychologically compromised. Interestingly, the group with combined TMPDS and cervical dysfunction demonstrated the highest level of psychoticism (a sub-type of personality traits) of the three groups, while the group with isolated TMPDS exhibited the highest levels of anxiety.

Although there is an association between bruxism and teeth malocclusion, bruxism has also been viewed as a parafunctional stress-relieving activity independent of malocclusion. The prevalence of bruxism appears to be significantly higher in middle-aged females employed in the tertiary sector, reporting high levels of stress (23,190). Ahlberg et al (190) used logistic regression analyses in a TMPDS-free sample population of mixed-category employees. Their findings showed that frequent bruxism (teeth grinding and teeth clenching) was significantly positively associated with severe stress experience (OR = 5.00) and the female gender (OR = 2.26). Factors of age (younger age group), number of visits to the medical doctor, and increases in administrative work were weakly associated with frequency of bruxism.

Submaximal levels of teeth clenching, with increases in sEMG activity in masseter, occur in the presence of physical and psychological stressors, irrespective of TMPDS symptomology (23,25,103,159,182,190,191). Studies comparing experimental stressors and associated teeth clenching have used examples of strenuous rowing sessions, stressful competitions, or fixed-time office tasks (176,182,191,192). Nicholson et al (191) found elevated levels of resting masseter activity in both TMPDS and non-TMPDS sufferers, in pre-task rather than during-task periods. However, the TMPDS group showed noticeably higher sEMG readings than their counterpart controls. It was concluded that bruxism is a fairly common response to psychophysiological stressors and may put one at risk of developing TMPDS (191).

Risk factors for the development of TMD and TMPDS have been discussed. However, the inter-relationship between the cervical spine and craniofacial areas are vital to the understanding of further contributory factors for TMD, and vice versa. The inter-relationship between the cervical spine and TMD will now be discussed.

2.4 The relationship between the cervical spine and TMD

2.4.1 Epidemiology

Literature has confirmed that there is a greater prevalence of cervical spine disorders in those with chronic TMD, independent of subgroup classification, than in persons without TMD (17,18,103). In addition, studies by Pallegama et al (193) and De Wijer et al (20) found strong associations between co-existence of cervical MSC and TMPDS specifically. According to Ciancaglini et al (22), individuals with TMD had a 2.37 fold increased risk for cervical pain ($p < 0.01$). However, findings based solely on prevalence data do not allow for investigation of the mechanisms behind the co-existence, or on a causal relationship (19,20).

The relationship between the cervical spine and the temporomandibular complex, though not well understood, is theorised to include biomechanical, neurophysiological, and psychological components (17,18,103). The research exploring these factors has been driven by the field of dentistry. This work has focused on the influence of TMPDS upon the cervical spine, and not vice versa (21). The components underpinning the relationship between the cervical spine and TMD will now be discussed.

2.4.2 Neurophysiological relationship between the cervical spine and TMD

The trigeminal nerve (cranial nerve V) and the first cervical nerves converge at the trigemino-cervical nucleus, currently considered the nociceptive nucleus for the entire head and upper neck (103,130) (Figure 2-1).

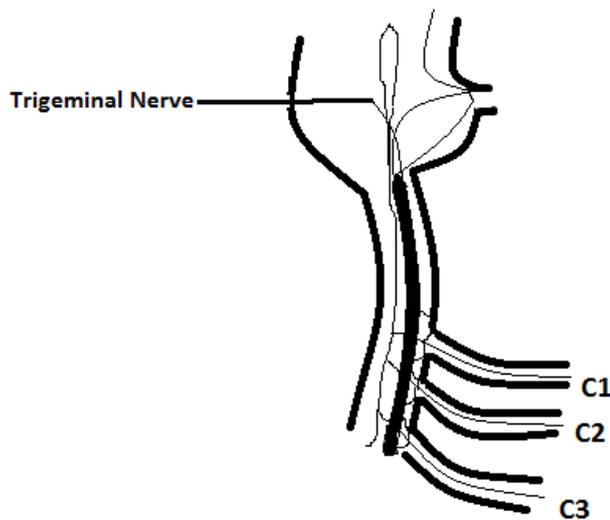


Figure 2-1: The trigemino-cervical nucleus and neurological connections [adapted from Bogduk (72)]

Experimental animal pain studies have been used in an attempt to reveal the mechanisms behind the relationship between the craniofacial and cervical areas. Animal pain studies have assessed and confirmed the reflex connections that exist between the nociceptors and mechanoreceptors of the TMJ and the posterior cervical fusimotor-muscle spindles (32,35,36). Based on the model of motor control adaptations to pain, irritants of mustard oil were induced via injection into the TMJ of rats of both sex, resulting in an increase in wire electrode EMG activity of the masticatory muscle spindles (32,65). Similarly, an increase in EMG activity of both the masticatory and posterior cervical muscle spindles was observed when inflammatory bradykinin was injected into the TMJ of cats (35).

Yu et al (32) and Hellstrom et al (35) were interested in the extent of respective fusimotor-muscle spindle output, and therefore were able to explore possible mechanisms behind muscle spindle output, traumatic pain and protective splinting of the mandible or cervical spine. They recorded similar durations of up to 25 minutes of sustained yet reversible afferent responses post-stimulation. Furthermore, mustard oil has been injected into rat paraspinal cervical tissues, with notable increases in both dorsal cervical and masticatory muscle activity (36).

Human experimental pain studies have obtained similar results to animal studies following noxious stimulation of the deep craniofacial or cervical tissue (30,194-196). However, the human studies only obtained weak increases in superficial and wire electrode EMG activity, whereas the animal studies had robust EMG increases. For instance, in two fairly similar human experimental pain studies, only relatively transient increases in resting EMG of the masseter was recorded post-pain induction (195,197). The increase in EMG activity was of shorter duration than the experimentally induced pain. The investigators concluded that acute human muscle pain was unable to maintain long-lasting resting muscle hyperactivity. Furthermore, Svensson et al (194) recorded an absence of increase in resting sEMG in the masseter muscle and a decrease in MVC occlusal force following experimentally-induced masseter muscle pain in humans. This concurs with results from human experimental pain studies done in chronic cervical MSC, as previously mentioned in the section on Muscle activity (p. 24) (109,126).

Possible reasons for the varying results found in animal and human studies may be due to the cognitive influence of pain found in humans (85,86). These findings further confirm that the motor control adaptation to pain does not follow a simple linear relationship in humans.

Conflicting evidence between previous animal and human experimental pain studies has led to further research regarding mechanisms behind human pain localization, referral and neuromuscular adaptation in the craniofacial and cervical regions. Due to current literature supporting gender influences on nociceptive results, most animal and human experimental pain studies now control for this through the use of strict inclusion criteria and gender-matched samples (88,89,98).

Svensson et al's cross-sectional studies (30,198) investigated the effects of experimentally induced masseteric pain in humans. These two studies confirmed that human experimental pain in the masseter is associated with significant increases in the resting sEMG activity in the masseter and posterior cervical muscles. Further, Svensson et al (30,133) examined the detailed effects when experimental pain induction was added in cervical tissue. Nineteen male participants, free of cervical spinal or TMD problems, were blinded to an intervention of random sequencing of injections of glutamate and isotonic saline (as a control) into the masseter and splenius cervicis muscles. Baseline readings for pain using the visual analogue scale (VAS) and EMG were taken. Mean levels of pain on the VAS (within 60 to 260 seconds post-injection) correlated significantly with the painful effects of glutamate injections, and not the saline. Results showed that with the head and mandible at rest, experimental cervical pain was not associated with increases in mandibular EMG activity (30). The investigators concluded that the site of pain may influence the nature of the pain response. The considerable convergence of craniofacial and cervical regions did not appear to follow a simple "*bidirectional phenomenon*", as further reflected in Svensson et al's study (133), p. 116.

A brief mention needs to be made of study limitations. Although Svensson et al (30) controlled effectively for potential sample bias or intervention bias, the small sample size may have influenced the statistical significance of the neuromuscular adaptive findings in the two closely associated regions of the masseter and posterior cervical muscles. In addition, no mention was made of normalisation of EMG data. Therefore their results should be interpreted with caution and not be considered as a generalisation for the nature of the pain response in the cervico-mandibular area.

The experimental investigation performed by Svensson et al in 2005 (133) followed the same methodology as their 2004 study (30). However, while the 2004 study recorded glutamate-evoked pain-related EMG activity, the later study's particular focus was on the characteristics of spread or referral into the masseter or splenius cervical muscles following experimental pain-induction. Twenty six healthy male participants provided pain scores on a VAS and pressure pain threshold data for analysis. One of the uses of the pressure pain threshold is as a measure for the detection of regional versus non-specific widespread pain.

An additional outcome measure, the pain rating index section of the McGill Pain Questionnaire (MDQ), was employed. The area of spread or referral for the experimental masseter pain was into the ipsilateral temporal or upper head, molar or TMJ areas, but did not extend into the cervical area. In contrast, the area of pain spread or referral for the experimental splenius pain was into the ipsilateral neck and occipital, temporal areas, and very occasionally into the teeth and masseter.

The clinical implications of the pathophysiological mechanisms of pain based on results from animal and human experimental pain studies may be questioned. However, the significance of the implied reflex connections between nociceptors and mechanoreceptors of the TMJ and the posterior cervical fusimotor-muscle spindles may explain the presence of the sensori-motor disturbances and pathophysiological mechanisms found in the cervical spine of those with TMD or vice versa. A limitation may be that, despite results having statistical significance, a simple extrapolation of result and implications into the clinical practice setting may not be appropriate. Consideration of the biopsychosocial model of pain by the investigators would have altered the study designs to allow for full consideration of biopsychosocial factors. These factors may have, as alluded to by literature on pain, played a role on the investigators' clinical measurements such as EMG, pressure pain threshold or the pain rating index.

The investigation of the neurophysiological inter-relationship between the cervical spine and the temporomandibular area is not complete without considering the interconnections between the biomechanical and psychosocial factors. These factors will be reviewed in the next sections of the review.

2.4.3 Biomechanical relationship between the cervical spine and TMD

According to a review by Catanzariti et al (21), changes in the crania-cervical junction are known to influence teeth occlusal patterns and mandibular activity through static and dynamic postural influences. Conversely, characteristics of the mandibular system are seen to influence the crania-cervical area through co-contraction influences of the masseter on the cervical musculature (26-29,31,137,180-182,199,200). The theoretical mechanisms underpinning the interactions between these two anatomical regions will be discussed further.

i. Influence of the cervical spine on the mandibular system

In the neutral cervical position, the cervical musculature supports and stabilises the head, and is responsible for holding the maxilla steady during almost all mandibular movements. Furthermore, in a neutral cervical spine position, the masticatory muscles are relaxed, creating a normal theorised 2 to 4 mm interocclusal distance between the teeth (38).

In a forward head posture (a small CV angle), the mandibular condyles move upwards and backwards, creating anterior teeth contact (34,37). It is theorised that the resultant tension on the masseter muscles bilaterally may stimulate bruxism and mandibular dysfunction (26,31,34,37,38,121). However, a recent systematic review cast doubt upon any conclusive influence of head and cervical posture on TMPDS, due to poor methodological quality (13). The authors suggested the need for better controlled studies with larger sample sizes and comprehensive diagnostic criteria for TMPDS. Since TMD is considered a heterogenous condition, it was stressed that TMD differentiation into subgroup categories of myogenous TMPDS, arthrogeous and mixed was vital for comparison within and between studies. The authors also stressed the importance of the consistent use of valid and reliable outcome measures for postural assessment of head and cervical posture.

ii. Influence of the mandibular system on the cervical spine

Kinesiological dentistry studies have, for the purposes of management of bruxism, TMD and therapeutic occlusal splintage, investigated the effects of teeth clenching on masseteric and cervical activity to understand the role that the mandibular system plays on the cervical spine (26-29,31,137,180-182,199,200).

Studies focusing on the cervical flexor muscles, in particular SCM, have reported on its co-activational role with the masseter muscle during experimental teeth clenching (26-28). At rest, the sEMG activity in SCM was less than 0.2% of its MVC, whereas, during experimental teeth clenching, there was a significant co-activational increase in SCM to 14% of its MVC (28). Ehrlich et al (27) and Tecco et al (26) similarly noted the percentage of MVC of SCM was significantly elevated during experimental teeth clenching. Similar findings were observed in the UT and, to a lesser degree, the trunk muscles. The former study's sEMG data was normalised, whereas the latter's was not. Despite this, it is theorised that there is indeed a relationship between the masseter and cervical flexor muscles during teeth clenching in normal participants. This link appears to exist in the form of neurophysiological interconnections and/or biomechanical influences of cervical posture.

With regards to the cervical extensor group of muscles, Tecco et al (26) and Ciuffolo et al (29) found no significant co-activation in the CE or UT during experimental teeth clenching in normal participants. Similar results were reported by Svensson et al (30). None of these studies mentioned normalisation of sEMG study data.

Discrepancies have been known to occur among study findings, due to methodological variations in sEMG application and a lack of detail describing data normalisation processes. Normalisation processes transform the sEMG data into a common format for comparison within and between individuals. Standardisation of electrode application, including normalisation processes, ensures sEMG reliability and reproducibility (201,202). In addition, limitations of both of these studies included samples of healthy individuals only, and the exclusion of individuals with cervical or TMPDS symptoms (26-30). The respective investigators highlighted the need for future research using sample populations of either isolated cervical disorders or TMPDS. Consequently, there would be further clarity on the pathophysiological relationship between TMPDS and the cervical muscles.

The role of the mandibular system in the prevalence of cervical involvement may be further extrapolated to characteristics of facial morphology and ethnicity. Tecco et al (31) revealed that in a sample of 60 adult Italian females, a “low” mandibular divergence or jaw retrusion (versus a “normal” or “high” mandibular divergence) was associated with a forward head posture (small CV angle, large cervical lordosis). Further, the presence of low mandibular divergence correlated with significantly higher masseter, CE and UT sEMG activity levels in the mandibular rest position. In addition, the sEMG resting levels of CE and UT in this group of females increased during experimental teeth clenching using masseter contractions. However, the study by Tecco and colleagues (31) was cross-sectional in design, and used sample populations that were free of TMD and cervical involvement. They could not assume causal relationships of form and function from their results, only describe potential neurophysiological or postural mechanisms at work.

iii. Influence of chronic cervical MSC on TMD

Further biomechanical investigations that were of interest and used specific sample inclusion criteria of either chronic MSC or TMD are listed below (26,28,31,137,180-182,199,200,200). For instance, De Laat et al (18) found that participants with TMPDS, who were free of cervical involvement, showed significant cervical segmental limitations at the C0 to C3 levels, tender points of the SCM and UT, and skin-fold hyperalgesia compared to controls.

Similarly, De Wijer et al (20) observed that patients with isolated TMD, especially within the myogenous subgroup, presented with objective signs and symptoms that were similar to those with isolated CSD. The investigators therefore claimed that orthopaedic tests for the cervical spine were of minor significance in discriminating between those with CSD and TMD. In addition, De Wijer et al (19) found objective similarities of TMJ joint sounds on active movement and TMJ palpation tenderness in those with isolated CSD. Unfortunately, a significant limitation to the latter descriptive studies was their lack of a control group. Confirming the need for control groups within CSD or TMD studies, some current studies report on common subjective and objective TMD features that are potentially prevalent in 8% to 45% of the general “control” community (17,18,172).

A reduction in both strength and endurance is commonly seen in cervical disability (117,118). A study by Armijo-Olivo et al (203) used a case group of 99 females with myogenous and mixed TMD that were free of cervical involvement, and a control group of 50 age-matched adult females to explore features of deep cervical flexor strength and endurance. This cross-sectional study reported no association between MVC of the deep cervical flexors and total effect size of TMD, when compared to controls. Further exploration by Armijo-Olivo et al (204) of musculoskeletal disorders in those with TMD revealed a significant inverse association between endurance of the deep cervical flexors and TMD disability (notably in the mixed TMD group).

Further, Pallegama et al (193) recruited a sample group of 38 patients with TMD (divided into subgroups of myogenous and disc disorders) and a matched sample of 41 healthy controls. The cross-sectional study attempted to explore the degree of cervical muscle involvement to the condition of TMD. Correlations were drawn between the chosen variables of resting sEMG activity, VAS pain levels of 4 areas of muscle pain (bilateral SCM and UT), gender, and TMD subgroup. Significant associations were observed for pain and resting sEMG, independent of gender. The pain-sEMG correlation was isolated to the SCM muscle in the myogenous subgroup only (193). However, study limitations may have reduced the emergence of potentially meaningful links between the cervical and temporomandibular systems. These limitations were considered to be a lack of normalisation of sEMG data, a lack of information regarding chronicity of diagnosed TMD, and a scarcity of additional subjective or objective measures for biopsychosocial pain, such as level of anxiety, depression or HRQoL. The research objectives and findings by Pallegama et al (193) were broadened by Pallegama et al (15) the following year, to include both physical and psychological characteristics. The psychosocial characteristics and relationship between TMPDS and the cervical spine will be demonstrated in the subsequent section (15).

2.4.4 Psychosocial factors

Pallegama et al (15) used matched mixed gender groups of isolated TMPDS, combined TMPDS and cervical spine disorders, and controls to compare psychological characteristics. Differences were significant between the groups, with those classified as having combined TMPDS and cervical disorders reporting being the most compromised, both physically and psychologically. This group demonstrated the highest level of psychoticism (a sub-type of personality traits) of the three groups. Furthermore, there was a significant reduction in HRQoL in those with combined TMPDS and cervical disorders (15,163), and this group had an equally high state of neuroticism (a further sub-type of personality traits) and anxiety as those with isolated TMPDS.

The cause-or-effect mechanisms behind factors of reduced HRQoL, high levels of anxiety, depression and sleep disorders remain elusive in those with combined TMPDS and cervical muscle pain, as well as in those with co-morbidity and/or multiple pain sites (15,46,79,80,163). However, it appears that a reduction in HRQoL and the presence of depression are more likely to be predictors of MSC, rather than as a result of MSC (3,15,41,46,59,157,163).

As mentioned earlier in the section on Health factors (p. 34), the importance of an individual's perceived interpretation of HRQoL and health status on the development of MSC problems must not be underestimated (2,40,46,59,70,157-159). In addition, impairment-disability correlations based on patient self-perceived disability may vary for different pathologies (87). This highlights the need for condition-specific instruments to measure self-perceived disability (87).

In a cross-sectional study, Olivo et al (12) used a novel, yet relevant, method of comparing NDI disability to TMJ disability in a sample population of females aged 18 to 50 years, consisting of 50 controls and 104 subjects with differentiated subgroups of myogenous and mixed TMD. The authors concluded that there are significant associations between level of TMD disability (whether myogenous or mixed) and level of cervical disability. According to multiple regression analyses, a Grade I level of TMD disability, according to the RDC/TMD instrument (APPENDIX VI, p. 182) (122), would increase the NDI score by 7.03 points ($p < 0.05$). Similarly, a Grade IV level of TMD disability would increase the NDI score by 19.32 points when compared to individuals without TMD. The presence of low to high levels of co-morbid TMD disability appears to significantly influence cervical disability. By way of a contrast, it would have been interesting to measure the effect of NDI disability on levels of TMD disability in those with isolated cervical dysfunction, however no literature appears to be available on this.

The biopsychosocial factors and pathophysiological mechanisms contributing to the development of chronic pain were mentioned previously in Section 2.1 (p. 5). Consequently, the biopsychosocial factors contributing to the development and maintenance of chronic cervical pain, and hence chronic cervical pain and disability are any of the factors influencing nociception, emotion and societal components. These factors may include ongoing peripheral nociceptive input arising from ongoing trauma, altered biomechanics and movement patterns. This spontaneous activity and input on neural cells is theorised to lead to spatial summation of sensori-motor integration, along with higher-order brain centre and psychological influences (9,62,132). In lieu of this, the neurophysiological, biomechanical and psychological links between the temporomandibular and cervical areas appear to become potent pathophysiological drivers toward the chronic syndromes of TMD and cervical MSC (17,18,103). The pathophysiological influences of the temporomandibular area on the cervical spine will now be discussed.

2.4.5 Pathophysiological relationship

The concurrent cervicogenic headache and CMD or TMD managed by physiotherapists in clinical practice is a well-known finding (205). Similarly, the use of Botulinum toxin (BOTOX) for the management of these concurrent syndromes is commonly reported in practice (206). Further, corrective dental procedures and orthodontic splintage may be used in the management of occlusal abnormalities, with resultant benefit to tension-type headaches (183).

As described earlier in Section 2.1.2 (p. 5), the pathophysiological process of chronic pain can be ascribed to the maintenance of peripheral- and/or central sensitisation at any point from the peripheral nociceptors to the cortical neurons in the brain (21,25). Due to the reflexive/biomechanical links between the masseter and antero-posterior cervical muscles recorded during bruxism (26-29,31,137,180-182,199,200), it may be proposed that the ongoing activation of masseter acts as a potential ongoing peripheral (nociceptive) driver to chronic cervical pain. The mechanisms behind the relationship, if any, may be causal (21,23-25), as a consequence of chronic pain (15,46,79,80,163), or concomitant.

There appears to be a minimal level of spontaneous muscular activity, or resting tremor, of the mandibular muscles in normal participants (207), compared to greater spontaneous activity in patients with TMPDS (31,86,181,207,208). Resting tremor has been described as normal rhythmical perturbations driven by the alternating activation of antagonistic muscles (207). Others have described this spontaneous muscular activity as the support against gravity given to the mandible in its rest position, through visco-elastic forces and low level masseteric tonic activity. Spontaneous muscular activity is seen as constant postural adjustment of the head and mandible that is evoked through feed-back and feed-forward mechanisms and is controlled by the CNS (121,209,210). Furthermore, this tremor appears to be influenced by nociceptive signals that modulate the output of the “*central pulsatile control generators*” (207).

As mentioned previously, Flor and Turk (85) and De Sade (86) observed elevated sEMG muscle-specific baseline tension and symptom-specific reactivity to psychophysiological “stressors” in those with TMPDS and tension headaches, compared to normal participants. These elevated sEMG activity levels were recorded for the masseter muscles and CE muscles. However, De Sade (86) also documented baseline muscle tension in normal participants during experimental psychophysiological stressors. The findings by Jaberzadeh et al (207) and De Sade (86) of minimal levels of spontaneous muscular activity at rest in the mandibular muscles in normal participants point toward the limited value of sEMG for TMPDS diagnosis. Further, it appears that psychological influences not limited to chronic pain may influence sEMG.

Jaberzadeh et al (207) looked at the tremor in the masseter muscle and the finger muscle of extensor digitorum longus in 12 normal participants. The sample comprised of seven male and five female adults. Their spectral density methodology compared tremor at rest, during constant-velocity movements and during experimental muscle pain induction into the masseter and finger. In the case of the masseter, experimental pain induction caused a reduction in the amplitude/power of the tremor at rest and during constant-velocity movement. In the case of the finger, experimental pain induction revealed a contrasting increase in amplitude/power of its tremor at rest and during constant-velocity movements. Yet, in both areas no change in the actual peak tremor frequencies at rest and during movement velocity were observed by experimental pain. The study indicated that peak frequencies of mandibular and finger tremor are unchanged by experimental pain, yet that mandibular and finger tremor present with pain-induced amplitude modulation in opposite directions. This may be due to the use of separate CNS oscillators. Furthermore, the findings from Jaberzadeh et al (207) may be extrapolated to infer that “*tonic*” muscular resting electrical activity is not necessarily a constant electrical signal.

In essence, there is a paucity of information about the spontaneous muscular activity of the mandibular muscles, and the possible nature of their involvement with CE, in those with chronic cervical pain who show no symptoms of TMPDS. In addition, there is no known record of the prevalence of teeth clenching in those with chronic cervical MSC who are free of TMPDS. The present study's literature review has approached the topic of chronic cervical pain by discussing the prevalence and theoretical framework of chronic pain conditions, using the biopsychosocial model. Yet the evidence for current theories on the aetiology of chronic cervical MSC is still unclear. The relationship between chronic cervical MSC and TMD may contribute to the development of chronic cervical MSC, due to biological and psychosocial factors. Therefore, measurement instruments most appropriate to cervical MSC and TMD are deemed necessary in order to ultimately assist in better describing the relationship. The relevant measurement instruments are described below.

2.5 Instrumentation

Effective management of a condition is assisted through the use of subjective or objective measurement instruments (71). However, not all operational measuring tools are feasible and affordable, thereby impacting on analyses and management of health-related and chronic pain-related conditions (211). Various subjective and objective outcome tools have successfully measured impairment, disability and participatory impact of chronic cervical MSC on individuals. As this study aimed to explore cervico-mandibular activity as a contributory factor to chronic cervical MSC in those without TMPDS, the measurement tools specific to the rationale are discussed below. The measurement instruments chosen for the present study appear in APPENDIX VI (p. 182).

2.5.1 Condition-specific measurement tools for chronic cervical MSC

A suggested reason for lack of medium to high methodological quality studies on chronic cervical MSC within office workers is the limited standardisation of inclusion criteria (6,71). The inclusion criterion in chronic cervical pain studies has typically been pain intensity levels (113,125). Examples of pain intensity measures have been the VAS or the verbal numeric scale (212).

However, with the increase in understanding of the pathophysiological mechanisms in chronic cervical pain, the emphasis is focusing less on assessment of signs and symptoms of pain, and rather toward the impact of pain.

One of the standard scales for functional evaluation of cervical pain or dysfunction is the Patient Specific Functional Scale (PSFS) (213). The PSFS subjectively quantifies activity limitation and measures functional outcome for patients. The score ranges from 0 (“*unable to perform the activity*”) to 10 (“*able to perform activity*”), using pre-injury levels as a marker for comparison. The strength of this scale lies in its extremely high responsiveness or sensitivity to change within the individual with cervical radiculopathy (214,215). However, although intra-individual comparisons using the PSFS are effective, inter-individual comparisons appear almost impossible, as descriptors for activity limitations are ascribed by the individual themselves (215).

The NDI is an additional measuring tool based on the framework of the biopsychosocial model of pain (83). The NDI is a 10-question assessment tool, with a maximum of five points per question. The total score provides categories of disability, ranging from “*no disability*” (0 to 4 points) to “*completely disabled*” (35 to 50 points). The NDI is a validated, reliable condition-specific modification of the Oswestry Disability Index for the low back (84). The NDI has been widely reported on for many population groups, and validated for its psychometric properties on cervical pain and disability (84,215). The NDI has been used in the work context (119,120,127,155). In addition, the NDI has been used in studies on TMPDS (12). One of its weaknesses is the applicability of all questions to respondents, such as the limitation posed by the response of the elderly or certain countries in its question pertaining to driving ability. This has been shown to contribute to unanswered questions and therefore missing data (215).

The Northwick Park Neck Pain Questionnaire (NPQ) is a nine question questionnaire (216). Each question consists of 5 parts, with a total of 0 to 4 points for each section. The NPQ has a similar structure and psychometric properties to the NDI. However, compared with the NDI, the NPQ has not been as extensively validated among different patient populations (215).

The NDI appears to be the strongest instrument with psychometric and condition-specific characteristics for the evaluation of cervical pain and disability. It allows for ease of application of the inclusion criteria classification of participants into two groups, namely a chronic cervical MSC group (NDI > 4) and a no pain group (NDI 0 to 4 points). In addition, the NDI has been used in other studies on TMPDS, which allows for comparison of data between studies (12). The NDI was used as an outcome measure in this study.

2.5.2 TMD screening tools

The epidemiology and pathophysiology of TMPDS and its associative role with the cervical spine has been widely studied (26-29,103,170). However, there is evidence of methodological limitations with regards to diagnostic criteria and methods of data collection (13,24,217). Further limitations appear to exist in the apparent lack of inclusion of non-patient control groups in blinded studies on MSC and TMD (13,17,18,22,29).

A recent systematic review found a limited number of medium to high quality studies on chronic cervical MSC among office workers (6). One of the possible reasons for limited numbers of good studies was poor diagnostic criteria for sample selection (6,71). Numerous chronic cervical pain studies have not excluded TMPDS, despite the high prevalence and coexistence of signs and symptoms in those with TMPDS and cervical MSC (110,116,123-125). Hence, one could argue for stricter exclusion criteria for chronic cervical samples, using the TMD screening tools discussed below.

Self-report questionnaires for TMD have been successfully used for data collection, due to the advantages of eliminating observer bias and employment of effective non-invasive methodology (122,184-188). The Helkimo clinical dysfunction index was developed for TMD categorisation (184). It was designed on the basis of five common symptoms of TMD, each judged according to a 0 to 5 point scale of severity. The total dysfunction score was simply the five symptoms severity score added together (0 to 25 total). In addition, the total dysfunction score allowed for allocation into “*mild*”, “*moderate*” or “*severe*” dysfunctional groups.

The Helkimo clinical dysfunction index is considered a simple test to administer, and due to its practicality, has been used extensively in epidemiologic TMD studies (218). However, the validity of this scale has not been determined (218,219).

In contrast, the psychometric TMJ-Scale is a 97-item questionnaire consisting of three domains, namely physical, psychosocial, and global domains (185-188). The global domain provides a single score useful for predicting the probability that a patient has TMD (218). The TMJ-Scale has been tested rigorously for reliability, validity, and responsiveness to change (185-188). Although the TMJ-Scale is accessible to patients in electronic form, it has been deemed lengthy by patients and, given the usage fees, it can be deemed an expensive tool for TMD categorisation purposes.

Another TMD measuring tool is the Research Diagnostic Criteria for temporomandibular disorders or RDC/TMD, which includes Axis I for assessing physical criteria, and Axis II for the assessment of pain-related disability and psychological status (122). The RDC/TMD tool provides specifications for a standardised clinical physical examination for differentiation into muscular, intra-articular and mixed psychogenous subgroups of TMD. In addition, self-report data via a self-administered History questionnaire forms part of the RDC/TMD. As the presence of common subjective and objective features in those with TMD is potentially prevalent in 8% to 45% of the general community, the RDC/TMD tool's sensitivity and specificity rating is important for diagnostic accuracy (17,18,172). The RDC/TMD tool has excellent sensitivity of ≥ 0.81 and specificity of ≥ 0.95 , highest for its myofascial diagnosis of TMD (220,221). The RDC/TMD has shown fair to good intra- and inter-rater reliability, once again greatest for the myofascial subgroup of TMD (222). A potential weakness of the RDC/TMD is that its reliability scores are influenced by frequently observed diagnoses, thereby limiting its widespread usage across all clinical settings (221,223).

The strengths of the RDC/TMD are its applicability to many population groups, as it has been formally translated into 18 languages (122,224). The standardised clinical examination has been used in several studies as a validated tool for TMD subgroup categorisation (180,181,225). The History questionnaire component of the RDC/TMD also has a high test-retest reliability. The History questionnaire is also freely accessible to clinicians and provides rapid screening suitable for telephonic purposes (122).

The Jaw Functional Scale (JFS) focuses on the daily functional limitations of those with TMD. It measures jaw disability in the form of a checklist, similar to the jaw disability checklist that forms a component of the History questionnaire section of the RDC/TMD (12). However, the JFS encompasses a more global function in addition to measuring jaw disability. Yet the correlation in convergent validity of this scale with other measures of pain and disability, such as the VAS, the dental version of the McGill Pain Scale, and the RDC/TMD has only recently been established. It is recommended for limited usage within specific population groups (226).

In summary, the TMD instrument of choice appears to be the RDC/TMD History questionnaire. The differentiation of type of TMD using the RDC/TMD was not required for this study. However its particular role as an exclusion tool for potential participants with TMD and TMPDS was relevant. Any score greater than a Grade 0 classification (based on "*pain intensity*", "*disability days*", and "*disability score*") would reflect the presence of TMD and TMPDS, and would be the criteria for exclusion of participants with TMD or TMPDS. In addition, the RDC/TMD History questionnaire includes a question on daytime teeth clenching. The presence of teeth clenching is of particular interest in the present study as a potential biopsychosocial influence in chronic cervical MSC.

2.5.3 Condition-specific physical activity measuring tools

Several studies of chronic cervical MSC emphasise the benefit of weekly leisure-related physical activity. Geldman et al (155) reported that early recovery from WAD was significantly more likely in both sedentary and non-sedentary police-force workers in individuals with medium to high levels of pre-injury physical activity, than for those with low levels. The NASA JSC Physical activity scale, a scale similar to the PSFS mentioned earlier (227), was used in Geldman et al's study (155). Both the NASA JSC Physical activity scale and the PSFS have high sensitivity for quantifying intra-patient changes in functional outcome. Yet, inter-patient comparisons appear almost impossible, as descriptors for physical activity levels are ascribed by the individual themselves (215).

A reliable validated questionnaire measuring weekly dose of both these items is the Computer Usage Questionnaire (CUQ) (111). The term "dose" may describe the frequency spent either sitting in a sedentary position or performing a leisure-related physical activity. The questionnaire has been employed in South African adolescent populations to reveal the negative influences of sedentary positions on MSC (111,228). However, the CUQ's validity and reliability has not been established in an adult population. Nevertheless, one may motivate for generic construct validity and reliability of the CUQ in adults, as similar findings to those reported in adolescents using the CUQ have been observed in previous studies using adult office workers (6-8,57,109,110).

Therefore, for studies in South African populations, the CUQ appears to be the instrument of choice. A further reason for its selection is its ease of application in measuring the weekly frequency of prolonged sitting, as well as the weekly frequency of leisure-related physical activity reported in office workers.

2.5.4 Pain measurement tools

The VAS (212) was briefly referred to in Section 2.5.1 (p. 62). The VAS is represented as a linear scale of 100 mm, and at opposite extremes of the scale are the terms “*no pain*” and “*worst pain imaginable*”. Pain rating is marked by the patient according to the scale (in mm), which is then translated by the administrator into a numerical pain score rating. The VAS has demonstrated good construct validity and reliability (158). Its speed and ease of use both for the patient and practitioner has been the reason for its frequent usage (113,125,212), however this has not always been the case with usage of the VAS by elderly or disabled patients (229).

Substitution with the verbal rating scale, which uses a set of adjectives that best describe how severe their pain is, with a corresponding numerical value, has yielded poor VAS-verbal rating scale correlation due to differences in intra-individual and inter-individual interpretation of adjectives (229).

The Standardised Nordic Questionnaire or Nordic Musculoskeletal Questionnaire (NMQ) provides descriptive information about pain, quantification of musculoskeletal pain, pain-related activity prevention, and area of pain (230,231). The original NMQ was designed for occupational health research and has been extensively used among occupational populations. However, it appears to lack rigorous reliability among these populations, leading to extended versions of this tool (215,232). There appears to be an improvement in reliability of the extended version of the NMQ among various MSC populations (215,232). For instance, the NMQ was recently employed by Natvig et al (14) to register the number/extent of widespread areas of musculoskeletal pain among office workers, through the use of its pain scale and body chart.

Similar to the NMQ, the Brief Pain Inventory (BPI) employs a body chart and pain severity score in the first half of the questionnaire (233). The second half of the BPI generates a “*pain interference score*”, a measure of functional interference from pain. The BPI was primarily constructed to assess the severity and impact of cancer pain. Subsequently, Keller et al (234) supported the reliability and validity of the BPI in non-cancer pain. The pain severity score on the BPI is generated by averaging the scores obtained on linear numerical scales for recent “*least*” and “*worst*” pain, “*average*”, and “*current*” pain intensity.

The BPI has more items on the severity of symptoms compared to the previously discussed VAS and Standard Nordic Questionnaire/NMQ. The BPI has psychometric properties designed to assess pain intensity and the impact of pain. Therefore its function as a generic measure of pain in most clinical settings is advantageous. Although the BPI is a slightly lengthier measure than most pain instruments, its ease of administration and simple structure and language has resulted in it being validated across several diverse language groups, including English and several other South African languages (233,235).

The widely-used McGill Pain Questionnaire (MPQ) includes a choice of 20 closed-ended adjectives to describe the patient's pain (236). The adjectives are divided into somatic, affective, evaluative and miscellaneous subcategories. The higher the total score, the higher the patient's pain experience. Further, a description of pain rating exists in the form of wording from "*no pain*" to "*severe pain*", as well as a linear scale for marking. A body chart is also present. The validity of the MPQ has been favourably compared to that of the BPI and the NDI (215,234). However, the use of detailed descriptors means that filling in of the questionnaire is time-consuming for the patient and may be challenging for those with lower education levels. An abbreviated version of the MPQ has been designed for pragmatic reasons, although its validity across all patient populations has not yet been fully investigated (237).

In summary, the first half of the BPI, that is the body chart and pain severity score, appears the most appropriate generic tool for measuring pain. In this study, information gathered from the area drawn on the body chart and average chronic pain severity score, served as confirmation for inclusion and exclusion criteria of participants into respective cervical pain and no pain groups.

2.5.5 Health related quality of life measuring tools

The EuroQoL-5D (EQ-5D) (238) is a validated outcome tool for the purposes of measuring self-reported health related quality of life. It provides a breakdown of state of health into “*mobility*”, “*self-care*”, “*usual activities*”, “*pain/discomfort*”, and “*anxiety/depression*” subgroups. Each subgroup is answered according to a level of severity (from “*none*” to “*moderate*” or “*extreme*”). In addition, a linear thermometer scale is included, for the marking of a point that best represents the patient’s perceived state of health today, on a vertical scale from 0 for “*worst health state*” to 100 for “*best health state*”. It has been validated for use in several South African populations (238).

The 36-Item Short-Form Health Survey (SF-36) uses physical and mental components to measure overall quality of life (239). The SF-36 measures eight domains of HRQoL, namely those of “*physical function*”, “*physical role function*”, “*bodily pain*”, “*general health perceptions*”, “*vitality*”, “*social role functioning*”, “*emotional role functioning*”, and “*mental health*”. It has been shown to have similarities in validation as a generic tool to the EQ-5D, yet its “*physical functioning*” domain has only recently been validated for use in the measurement of “*mobility/disability*” according to the ICF. Strengths of the SF-36 lie in the fact that it is one of the most commonly used HRQoL measuring tools, and it has been employed across ethnic groups (240). Although it has been translated into over 120 languages, it remains lengthy to complete and has low completion rates. An additional weakness is that the SF-36’s questioning on physical activities does not focus on the construct of cervical pain and disability, in contrast to the NDI which, as mentioned earlier, is a condition-specific measurement tool that focuses on cervical pain and disability (83). Further, an annual license fee limits access to the SF-36.

The Hospital Anxiety and Depression Scale (HADS) (241) has been used in a wide range of clinical groups including breast cancer, renal and heart disease as well as in chronic MSC to measure anxiety and depression (241-243). The tool is limited to measuring anxiety and depression in isolation, and does not include criteria for the measurement of HRQoL.

In comparison with the alternatives, the EQ-5D is a psychometrically robust and user-friendly instrument for measuring state of health in a sample of South African chronic cervical MSC participants and controls. It has been validated for the target population, and is a short and simple tool to administer.

2.5.6 Surface electromyography

Surface EMG is considered a validated “*gold standard*” diagnostic tool for the monitoring of neuromuscular activity and muscle interactions, although it should not be regarded as the sole diagnostic tool for pathology (130,202,208). According to the literature, standardisation of sEMG application ensures its reliability and reproducibility (201,202). Specifically, criteria for good reproducibility include electrode type, size, placement, inter-electrode distance, lack of movement of electrodes and adequate training of raters (201,202). Validity and systematic error for sEMG usage may be accounted for by differences in age and sex, as well as thickness of subcutaneous fat (122,243). To allow for comparison within and between individuals, data should be transformed into a common format, by the normalisation of all root mean square (RMS) average values as a percentage of each respective muscle’s MVC (201).

The sEMG muscles of choice for human experimental and clinical pain studies on cervical MSC have typically been the UT, SCM, and anterior scalene cervical muscles (113,116,117,134,204,244). The reason for their selection in previous studies has been due to their respective anatomical access, potential for stored tension, and continuous motor impairment following first episode of cervical pain. Fewer studies have been performed on the CE muscle group in the presence of chronic cervical pain (7,112,116,117,119,120,125,134,244,245) in contrast to the numerous cross-sectional studies analysing strength, endurance and recruitment strategies in the UT, SCM, and anterior scalene cervical muscles during office tasks.

The CE muscles were chosen for evaluation in this study, due to their antigravity role during computer usage (Section titled Occupational activities, p. 22), their relationship with cervical disability (Section titled Muscle activity, p. 24), and their biomechanical relationship with the masseter during teeth clenching (Section 2.4.3, p. 55) (5,7,26,30,112,119,120). In addition, the superficial nature of the CE makes it easily accessible for evaluation with sEMG (103). The use of sEMG in this study was to explore kinesiological factors and not to determine diagnosis, and was employed as a measure of masseter and CE activity.

2.6 Summary of the literature

The pathophysiological mechanisms underlying chronic pain remain unclear (44,54,56). Some of the lack of clarity appears to stem from methodological variations in definition, prevalence and the use of various measurement tools in chronic pain research (40,41). Similarly, there remains a dearth of information on the pathophysiological mechanisms in chronic cervical MSC in office workers (3,75,76).

The prevalence of chronic cervical disorders is high, both in developing (3,40,49) and developed countries (1,4,51). Prevalence is also measured by its propensity to disable individuals (4). Cervical MSC symptomatology, ranging from low to high levels of pain and disability, has been shown to influence work attendance and productivity and subsequently has economic impact on individuals and society (5-8). Factors recognised to contribute to chronic cervical MSC include age (3,91-94), gender (2,8,40,41), genetics (97,100), posture (7,66,75,105,107,228), occupational activities (6-8,57,109,110), muscle activities (85,86,109,110,116-118,126,131,132), trauma (64,90,147-149), health-related issues (153-155), catastrophisation/anxiety/depression/mental load and psychosocial issues (15,163), and socio-economic aspects (3,40,49). However, further biopsychosocial factors appear to exist in syndromes that are co-morbid to cervical disorders (11-23). It appears that the high prevalence of co-existent signs and symptoms of the cervical and temporomandibular areas may be a key to further mechanisms behind the incidence, persistence and maintenance of chronic cervical MSC in female office workers (11-23). Further, the biomechanical, neurophysiological, and psychological components of the relationship between the cervical spine and TMPDS is as yet not well understood (21,23-25).

The present study, to be discussed in Section 3, has explored the cervico-mandibular muscles of the masseter and CE muscles in those with chronic cervical MSC, at the exclusion of those with TMPDS. Potential differences and relationships between cervical disability and the biopsychosocial factors of pain, occupational and leisure-related activities, teeth clenching habits and HRQoL will assist in establishing further understanding of the pathophysiological mechanisms in chronic cervical MSC.

University of Cape Town

CHAPTER 3: METHODOLOGY

3.1 Research design

This study had a descriptive, cross-sectional design with single-blinding.

3.2 Participants

A sample of convenience was utilised. Participants consisted of female students and staff that were recruited from the University of Cape Town (UCT).

3.2.1 Inclusion criteria

Female volunteers aged between 21 to 45 years were included in the study [a similar age-group used by previous studies (28,31)]. Males were excluded from the study due to recognised gender differences in pain processing (88,89,99). The female sample were required to show good comprehension of written and oral English as the validated questionnaires were in English. The initial telephonic screening process tested for this.

The NDI was used to group participants into a chronic cervical pain group and a no pain group. Participants in the pain group were required to be categorised with “*mild disability*” to “*severe disability*” on the NDI (83); and report the presence of cervical pain for at least three to six months in the past year, and/or experience at least four recurrent episodes of cervical pain in the past year lasting three or more days (17,246).

Participants in the no pain group were required to be categorised with “*no disability*” on the NDI (83). In addition, participants in the no pain group were required to be free of pain (for which they required treatment) anywhere in the body for seven days prior to testing, and on the day of testing (17).

3.2.2 Exclusion criteria

Volunteers reporting TMD symptoms on the RDC/TMD History questionnaire (122) were excluded from the study. In addition, participants in the pain group were excluded if they were receiving any form of cervical treatment other than Schedule One or Two analgesics at the time of the study (17,246). Other exclusion criteria included: a history of fracture, trauma or surgery to the mandibular or cervical area; a history of prosthodontic or orthodontic procedures; removal of more than one tooth per quadrant (excluding third molars) (28,180); and a history of any systemic illness such as fibromyalgia, myositis or myalgia. In addition, participants with BMI greater than 30 kg/m^2 were excluded, due to the confounding influence of subcutaneous fat on sEMG (243).

3.2.3 Sample size determination

Similar cross-sectional studies have employed sample sizes ranging from 12 to 33 individuals (28,29,180). Sample size was calculated based on reported differences in sEMG levels of the CE in individuals with and without cervical pain (119,120). Using a significance level of $p < 0.05$ and a power of 0.9; with a minimal detectable difference between groups of $1.3 \pm 2.5 \mu\text{V}$ on sEMG activity of the CE, a total of 42 participants (21 in each group) were required for the study. To allow for the potential loss of participants, a total of 49 participants were recruited and screened for this study.

3.2.4 Recruitment and screening

The study proposal was approved by the Faculty of Health Sciences Human Research Ethics Committee (HREC REF 316/2010) (APPENDIX I, p. 168). Subsequently, permission was obtained from the respective Health Sciences' Student Affairs and Human Resource departments for access to UCT students, staff and faculty. Access via email and print media was granted for recruitment purposes (APPENDIX II, p. 169). Printed advertisements were placed on Faculty of Health Sciences bulletin boards, and emails were sent through the Faculty mailing list. The recruitment advertisement stated that participation was voluntary, without financial compensation, and detailed contact telephone numbers for the research assistant and all details of eligibility, study procedure and location (APPENDIX III, p. 171). A systematic telephonic screening process was performed by the research assistant with all interested individuals (APPENDIX IV, p. 173). General questions on previous trauma and medical and dental history were asked to screen for inclusion and exclusion criteria (83,180,182,191,224,233). In addition, questions pertaining to level of pain and disability in general, and of the temporomandibular and cervical areas were asked in order to further assist with inclusion and exclusion criteria. These questions on pain and disability were selected from the RDC/TMD History questionnaire, BPI and NDI (Refer below to Section 3.3, p. 77). The principal investigator (PI) remained blinded to the screening process to eliminate bias prior to sEMG data collection and comparison. Volunteers that met the inclusion criteria for the study were invited to attend the Department of Health and Rehabilitation Sciences at Groote Schuur Hospital, Cape Town for obtaining informed consent (APPENDIX V, p. 176) and data collection. The recruitment and screening process of participants is presented in Figure 3-1 (p.77).

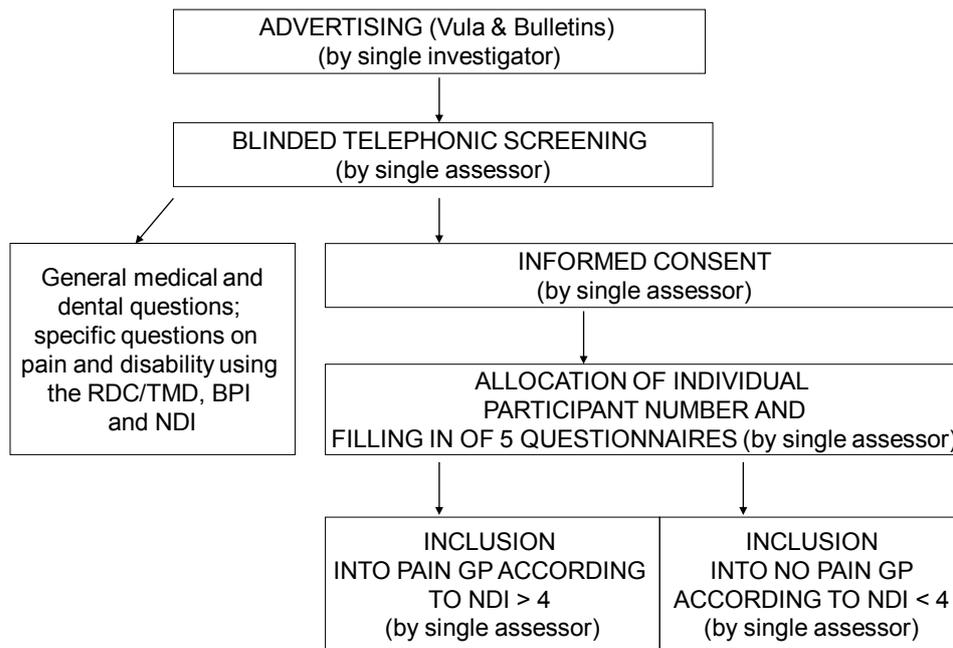


Figure 3-1: Recruitment and screening of participants

3.3 Measurement instruments

The measurement instruments selected for the study were the RDC/TMD History questionnaire (122), the NDI (83), the CUQ (111), the BPI (233), and the EQ-5D (238) (APPENDIX VI, p. 182). Muscle activity of the CE and masseter muscles was recorded using sEMG. Cervico-mandibular activity was measured at rest, during posterior tooth contact (light clench), and during MVC in the sitting position. The use of these six instruments within this study was as follows:

3.3.1 The Research Diagnostic Criteria for temporomandibular disorders

Aspects of the RDC/TMD History questionnaire on pain and disability of the temporomandibular area formed part of the telephonic screening process. Any score greater than Grade 0 classification (based on “*pain intensity*” from questions 7 to 9, “*disability days*” from question 10, and “*disability score*” from questions 11 to 13) reflects the presence of TMD, and confirmed exclusion of those individuals from the study (122). Once included into the study, participant responses to the complete RDC/TMD History questionnaire were used. However, minor adaptations had been made to the RDC/TMD History questionnaire, which were validated during the pilot study prior to the actual study. The adapted RDC/TMD History questionnaire had questions 24, 26 to 28 and 30 to 31 that were excluded, as demographic information on education; unemployment and finance were not a focus of the study. In addition the sample was a relatively homogeneous group. In contrast, question 25 on ethnic groupings was maintained but adapted for the South African context, as this type of demographic information remains useful for comparability purposes with historical research (177). The changes made did not alter the comparability of the results with other studies.

The adapted RDC/TMD History questionnaire has a section on the presence/absence of nocturnal teeth grinding, however the section on daytime teeth clenching habits was used as the indicator for the study. Previously, evidence of tooth abrasion was used as an indicator of nocturnal teeth grinding and teeth malocclusion (103,170). However, the validity and reliability of methods to assess nocturnal teeth grinding has been questioned and isolated daytime teeth clenching has been suggested as a more valid measure (24). Therefore, self-report of isolated daytime teeth clenching was used for analysis, and precluded any statements regarding nocturnal teeth grinding in the RDC/TMD.

3.3.2 The Neck Disability Index

The NDI (83) was used to allocate participants to the chronic cervical pain group and the no pain group. Categorisation into the pain versus no pain group was based on a total raw score greater than four (on a scale of 0 to 50) on the NDI, or less than or equal to four on the NDI. The NDI has been validated for use in office workers to measure levels of combined pain and disability of the cervical spine (83).

3.3.3 The Computer Usage Questionnaire

The CUQ measurement instrument (111) was used in the present study to identify work patterns and computer usage as a potential contributing factor to chronic cervical MSC. Permission was granted from the author to make adaptations to the CUQ necessary for the study's target population. Changes included: the term "school" replaced with "office"; "weekly" number of hours spent at the computer and during sports replaced with "daily" number of hours; sections on pain and HRQoL were excluded due to duplication of information within the study; sections on past medical history and music-based questions were not relevant, and were excluded. The CUQ is a valid and reliable tool for assessing aspects of school activities and computer usage in young adolescents.

3.3.4 The Brief Pain Inventory

The BPI employs a body chart, a "pain severity score" and a "pain interference score". In the present study, information gathered on area (body chart) and pain severity served as data on the side of pain for comparison with sEMG activity. The pain group was required to have experienced pain anywhere in the area of the cervical spine extending from the occiput to the lateral shoulders and interscapular areas. The no pain group requirements were for participants to be free of pain anywhere in the body during the previous seven days or on the day of testing. The questions relating to the Pain interference score (questions 7 to 9) were excluded as information on pain interference with activity was obtained through the NDI. The BPI has been validated for use in cancer and non-cancer research, including musculoskeletal studies (233,234).

3.3.5 The EuroQol 5D quality of life questionnaire

The EQ-5D was used to evaluate participants' HRQoL (238). The numeric value for perceived health status, as well as the domains for mobility, self care, usual activities, pain/discomfort and anxiety/depression was used to determine overall HRQoL. The EQ-5D has been validated to measure HRQoL in a South African population (238).

3.3.6 Surface electromyography

Surface EMG was used to determine masseter and CE activity. The Myotrace 400 EMG recorder used in the present study was set up to measure the 4-channel activity of the CE and masseter muscles bilaterally (Figure 3-3 , p. 83) (247). The technical specifications of the MyoTrace 400 may be found in APPENDIX VII, p. 209).

Standardised methodology was employed for SEMG testing (202). "AMBU-Blue sensor" paediatric electrodes were used. These electrodes (Type N-00-S) were disposable, self-adhesive Ag/AgCl electrodes with a small diameter conductive area (0.8 cm), which reduced cross-talk (247). Fixed location points were used, with fixed inter-electrode distances of 20 mm in parallel to muscle fibre direction (110,125,130,182,202,217,248). Electrode cable fixation ensured lack of cable movement or tension (201,202). According to literature, standardisation of sEMG application ensures its reliability and reproducibility Specifically, criteria for good reliability and reproducibility involves standardisation of sEMG application. These criteria include electrode type, size, placement, inter-electrode distance, lack of movement of electrodes and adequate training of raters (201,202). Further, sEMG validity and systematic error may be accounted for by differences in age and sex, as well as thickness of subcutaneous fat (122,243).

3.4 Pilot study

A pilot study was conducted with a sample size of five participants. The pilot study allowed for testing of the procedure, from recruitment and screening, to the completion of questionnaires and sEMG application. No additions, deletions or changes were deemed necessary as a result of the pilot study. It took participants a maximum of 20 minutes to complete the questionnaires.

3.5 Procedure

Recruitment of volunteers through advertisement was followed by the telephonic screening process for inclusion into the present study. Participants were invited to attend testing at the Old Main Building, Groote Schuur Hospital, Cape Town. On arrival, participants were given an information sheet and provided with the opportunity to ask questions prior to enrolment into the study (APPENDIX V, p. 176). Once informed consent was obtained, each participant was allocated a unique identifying number and asked to complete five questionnaires, namely the adapted RDC/TMD History questionnaire, the NDI, the CUQ, the BPI, and the EQ-5D (APPENDIX VI, p. 182). On completion of the questionnaires, the research assistant collected and assigned the category of pain and no pain group to each participant according to their NDI score. All completed questionnaires were stored in a sealed opaque envelope by the research assistant and opened by the PI only once the data for the entire study had been collected. The PI was blinded to the groups prior to completion of sEMG data collection and data analysis.

Participants were prepared for sEMG testing by the research assistant. This involved having the hair tied back and having the facial and cervical skin cleaned with an alcohol swab to allow for cervical area accessibility for sEMG application and recording by the PI. The same venue and chair was used throughout testing to minimise intervention and performance bias during sEMG data collection.

Participants were seated for testing in the allocated chair, which provided back support up to scapular height, without head support. The chair was height-adjustable to ensure knees and hips were flexed at 90° (28,248). Four disposable Ag/AgCl circular electrodes with a 0.8 cm diameter were applied to the left and right masseter and CE muscles (247).

Electrode placement for the superficial masseter was over the body of the muscle 20 mm anterior and 10 mm above the mandibular angle, along the gonion-cantus line (130,182,217,248). The inter-electrode distance for the second masseter electrode was 25 mm above the first, measured from centre point to centre point (182).

Electrode placement for the CE was according to anatomical landmarks, 10 mm lateral to the C4 and C5 spinous processes, with an inter-electrode distance of 20 mm (110,125,130). All electrodes were placed parallel to fibre orientation (202). A ground electrode was applied to the upper thoracic vertebra (119). Once sitting in a comfortable upright position, electrodes were fixed in place using Micropore® (Figure 3-2).



Figure 3-2: Masseter and CE electrode placement

The Myotrace 400 EMG recorder (247) was used to measure the 4-channel activity of the CE and masseter muscles bilaterally (Figure 3-3, p.83).

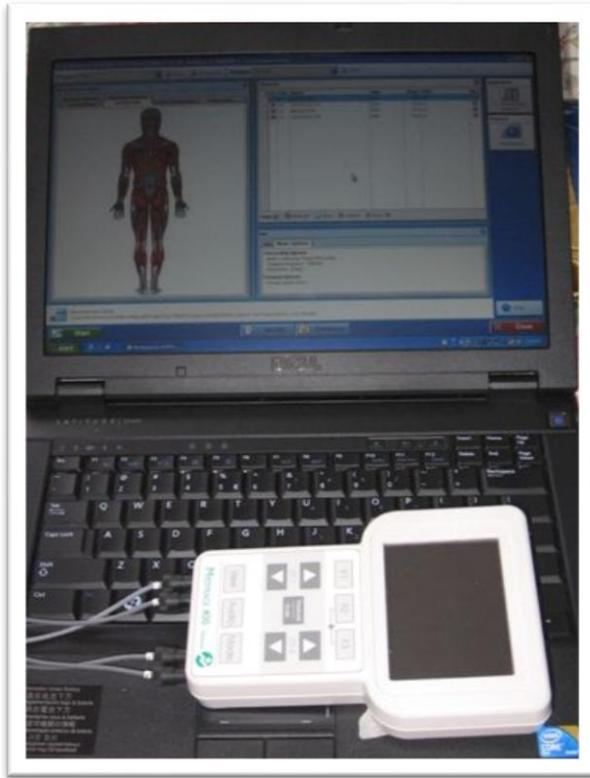


Figure 3-3: Myotrace 400 sEMG recorder

Prior to any sEMG recordings, each participant was allowed five minutes to settle quietly in the chair to achieve a relatively stable baseline sEMG. Three types of sEMG analyses have been described below. Each type was practised as a trial run, without creating fatigue. For each of the respective recording window periods, the participant was blinded to the exact onset and termination of the recording done by the PI. The participant merely followed the verbal instructions of the PI, who used sEMG recording markers a few seconds post-instruction. In this way, the potential influences of fear or anticipation on performance and results was reduced.

The first set of sEMG recordings were of 10 seconds duration, similar to previous literature (28,29), with a 30 second interval, and repeated three times. During each 10 second recording, the participant was requested to sit with the trunk in an erect posture and the head in a comfortable position. Participants were cued to focus their eyes on a spot directly forwards, avoiding any head or body movement whilst maintaining a relaxed neck and shoulder posture with both hands resting on the lap (28,29). They were visually monitored by the PI.

Secondly, the instructions and procedure for the subsequent set of sEMG recordings were identical, although on this occasion each participant was verbally cued to maintain the position of "*first tooth contact*", short of a light clench (137). Quality and maintenance of the intercuspal position of first tooth contact was achieved during the practice trial and recording window periods, under supervision of the PI with the use of the sEMG signal on the Myotrace 400 screen (225). The use of an intraoral compressive-force sensor was not an option due to lack of availability and expense (248).

Lastly, after one practice run, the respective MVC for CE and masseter was recorded. The MVC recordings were of three seconds duration, repeated twice, with a rest period of 60 seconds between contractions to avoid fatigue (12,125). MVC values for each muscle group are required for normalisation of sEMG data. Typically, the MVC is recorded prior to other readings however, due to the possible influence of MVC on resting levels of activity in the muscles, MVC values were recorded last.

Maximal resisted cervical extension for the superficial CE was performed against an air pressure sensor inflated to 20 mm Hg. The pressure gauge was held in view by the PI for participant feedback along with verbal encouragement (249). This was similar to the technique employing a height-adjustable padded steel bar, temporarily attached to the chair, as described by Szeto et al (125). Similarly, for normalisation of masseter sEMG data, MVC was performed during maximum teeth clenching in the intercuspal position, while a colour display was held in view by the PI for participant feedback along with verbal encouragement (28,248). Once the sEMG data collection was completed, participants were assisted with removal of the electrodes and provided with an information pamphlet (APPENDIX VIII, p. 211).

3.6 Data analysis

Analyses and processing of sEMG data were achieved through rectification, filtration (lowpass filter of 50 Hz, bandpass of 15 to 500 Hz) and smoothing procedures of sEMG values into $\mu\text{V/s}$. The average value of force over the repeated contractions was used. All root mean square (RMS) average values were expressed as a percentage of the MVC for normalisation purposes, to transform the data into a common format (201).

3.7 Statistical analyses

The present study data were analysed using Statistica (250). The Shapiro-Wilk test for normality showed the recorded variables were not distributed normally for any of the socio-demographic and biopsychosocial variables. Similarly, the sEMG data (during the experimental average recording window periods of 0 to 5 and 6 to 10 seconds of sitting at rest and during light clench) were not normally distributed despite normalising the data. Outliers (greater than two standard deviations from the mean) were removed; however, this did not influence distribution of the data.

Consequently, comparisons were made between the pain and no pain groups for the socio-demographic, biopsychosocial, and sEMG variables (at rest and for the rate of change of activity during light teeth clenching) using the Man-Whitney U and chi-squared (X^2) tests. Associations between the variables of cervical disability and pain, disability and occupational and leisure-related activities, and disability and perceived health status were performed using Spearman correlation tests. Further, associations were explored between cervical disability, pain and resting cervico-mandibular sEMG data.

Lastly, secondary analysis was conducted using the variables of teeth clenching and anxiety/depression as grouping variables. Differences in biopsychosocial factors between each respective group was analysed using Man-Whitney U and X^2 tests. All data were presented as the mean \pm standard deviation (SD). Statistical significance was accepted as $p < 0.05$.

3.8 Ethical considerations

The study was conducted in accordance with the principles of the (251)Declaration of Helsinki (251). The research proposal was approved by the Faculty of Health Sciences Human Research Ethics Committee, UCT (HREC REF: 316/2010) (APPENDIX I, p. 168). All participants were required to complete the informed consent form prior to their involvement in the study (APPENDIX V, p. 176). Participants completed the consent form at the familiarisation session, and were given an opportunity to discuss the study requirements, including testing procedures, the potential risks and benefits, and any questions and concerns. It was made clear that all information obtained would be held in confidence and that the participants could withdraw at any time. In addition, all completed questionnaires would be stored in a sealed opaque envelope by a research assistant and opened by the PI only once all of the data had been collected and analysed.

3.8.1 Risks to participants

There were no risks associated with the completion of any questionnaires. The Myotrace 400 model transmits a deliberate radio signal that is harmless to human beings. The Myotrace was used in an area further than one meter from any high frequency surgical equipment, to prevent any potential interference (247). Total exposure per participant for the entire data collection process was limited to 15 minutes. Any uncertainty or fear of the unexpected was avoided by familiarising the participants prior to testing. Alcohol swabs and micropore were non-allergenic and gentle on the skin.

Electrodes used were participant-specific single-use electrodes and were disposed of once sEMG capturing was complete. The shock hazard was eliminated by first attaching electrodes to the machine snaps. No exacerbation of cervical discomfort was anticipated. The sEMG recordings were measured at rest, and the MVC repetitions were kept to a minimum to avoid pain or fatigue (12). Any possible reproduction of pain during MVC was countered by allowing for a sub-maximal voluntary contraction. Both maximal and sub-maximal voluntary contractions are suitable for normalisation of data (201).

3.8.2 Benefits to participants

On completion of data collection, participants were provided with an evidence-based information pamphlet on prophylactic cervical care, including the optimal resting position for the cervical and mandibular systems (APPENDIX VIII, p. 211). Lists of physiotherapy practices (other than those services of the PI) were provided only on request, to avoid potential conflict of interest. It was made clear that all information obtained during data collection would be held in confidence. Beverage refreshments, a physiotherapy information pamphlet, and a parking fee reimbursement were offered on completion. Participants were not provided with the results of the study.

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CHAPTER 4: RESULTS

This chapter will begin by describing the socio-demographic and biopsychosocial profile of the sample. The results of sEMG activity of bilateral masseter and CE, at rest and during light teeth contact will then be presented. The final section explores relationships between biopsychosocial variables and resting cervico-mandibular sEMG activity levels.

4.1 Sample

A total of 49 females responded by telephone to the bulletin and email recruitment advertisements. Seven volunteers were excluded by the assessor using the telephonic screening process. Reasons for exclusion were: participants were not UCT employees ($n = 2$); participants outside the age range of 21 to 45 years ($n = 3$); removal of more than one tooth per quadrant (excluding third molars) ($n = 1$), and receiving current cervical treatment ($n = 1$).

Forty two participants were included in the study. Following screening of the 42 participants, 20 participants formed the chronic cervical pain group, and 22 participants formed the no pain group. All participants completed the data collection procedure. No participants withdrew from the study.

4.2 Socio-demographic profile

Descriptive statistics for the sample are presented in Table 4-1. Results are presented for the total sample (N = 42), the pain group (n = 20), and the no pain group (n = 22).

Table 4-1: Socio-demographic characteristics (N = 42)

Profile variables	Sample (N = 42)		Pain group (n = 20)		No pain group (n = 22)		Test statistic	p-value
	Mean ± SD	Frequency (%)	Mean ± SD	Frequency (%)	Mean ± SD	Frequency (%)		
Age (yrs)	27.80 ± 6.32		27.35 ± 5.15		28.23 ± 7.33		$U = 217.50$	0.96
BMI (kg/m²)	24.33 ± 5.29		23.69 ± 5.74		24.90 ± 4.92		$U = 171.00$	0.22
Occupation							$\chi^2 = 0.35$	0.55
Student		54.76		50.00		59.09		
Staff		45.24		50.00		40.90		
Sit: h/wk	26.15 ± 15.61		26.13 ± 13.65		26.18 ± 17.53		$U = 217.00$	0.95
Sport: h/wk	1.01 ± 1.82		0.53 ± 0.99		1.45 ± 2.26		$U = 189.50$	0.45
Hand dominance							$\chi^2 < 0.01$	0.94
Right		95.24		95.00		95.45		
Left		4.76		5.00		4.55		
Ethnic group							$\chi^2 = 2.33$	0.68
White		47.62		45.00		50.00		
Black		16.67		15.00		18.18		
Indian		2.38		5.00		0.0		
Coloured		30.95		30.00		31.82		
Other		2.38		5.00		0.0		

There were no significant differences between the two groups for age ($U = 217.50$; $p = 0.96$), BMI ($U = 171$; $p = 0.22$), occupation (student or staff) ($\chi^2 = 0.35$; $p = 0.55$), and hand dominance ($\chi^2 < 0.01$; $p = 0.94$). Further, no significant difference between groups was found for total hours per week of computer usage (26.13 ± 13.65 h/wk vs 26.18 ± 17.53 ; respectively) ($U = 217.00$; $p = 0.95$). In addition, there was no significant difference between groups for total number of hours per week spent with sports involvement (pain group = 0.53 ± 0.99 h/wk and no pain group = 1.45 ± 2.26 h/wk) ($U = 189.50$; $p = 0.45$). The two groups were also well-matched for ethnicity.

4.3 Disability and pain

The study used two instruments to measure pain, namely the pain severity score from the BPI and the pain/discomfort subgroup index of the EQ-5D questionnaire. A one-way ANOVA was conducted between the pain subgroup of the EQ-5D and the BPI to determine the concurrent validity of the two pain instruments. Results indicated good concurrent validity between the pain severity score from the BPI and the pain/discomfort subgroup index of the EQ-5D questionnaire ($[F(1, 40) = 77.82, p < 0.01]$).

The NDI and pain severity score from the BPI scores for the total sample and for the individual groups are presented in Table 4-2.

Table 4-2: Cervical disability and pain severity score (N = 42)

	Sample (N = 42)	Pain group (n = 20)	No pain group (n = 22)	Test statistic	p-value
Instruments	Mean ± SD	Mean ± SD	Mean ± SD		
NDI	6.29 ± 5.64	11.00 ± 4.72*	2.00 ± 1.20*	$U = 0.0$	p < 0.01
BPI	2.41 ± 2.08	3.84 ± 1.54*	1.11 ± 1.61*	$U = 50.00$	p < 0.01

The NDI scores ($U = 0.00; p < 0.01$) and pain severity scores from the BPI ($U = 50.00; p < 0.01$) were significantly higher in the pain group, compared to the no pain group. Data from the BPI's body chart revealed that the average area of chronic posterior cervical pain reported in the pain group was mainly bilateral.

4.4 Teeth clenching

The prevalence of daytime teeth clenching habits are presented in Table 4-3.

Table 4-3: Prevalence of teeth clenching (N = 42)

	Sample (N = 42)	Pain group (n = 20)	No pain group (n = 22)	Test statistic	p- value
	Frequency (%)	Frequency (%)	Frequency (%)		
<i>Daytime teeth clench</i>				$\chi^2 = 6.48$	0.01
Not reporting daytime teeth clenching	69.05	50.00*	86.36*		
Reporting daytime teeth clenching	30.95	50.00*	13.64*		

The presence of daytime teeth clenching as a parafunctional activity was significantly greater in the pain group ($\chi^2 = 6.48$; $p = 0.01$). Fifty percent of the pain group reported teeth clenching compared to 13.64% of the no pain group.

4.5 Health related quality of life

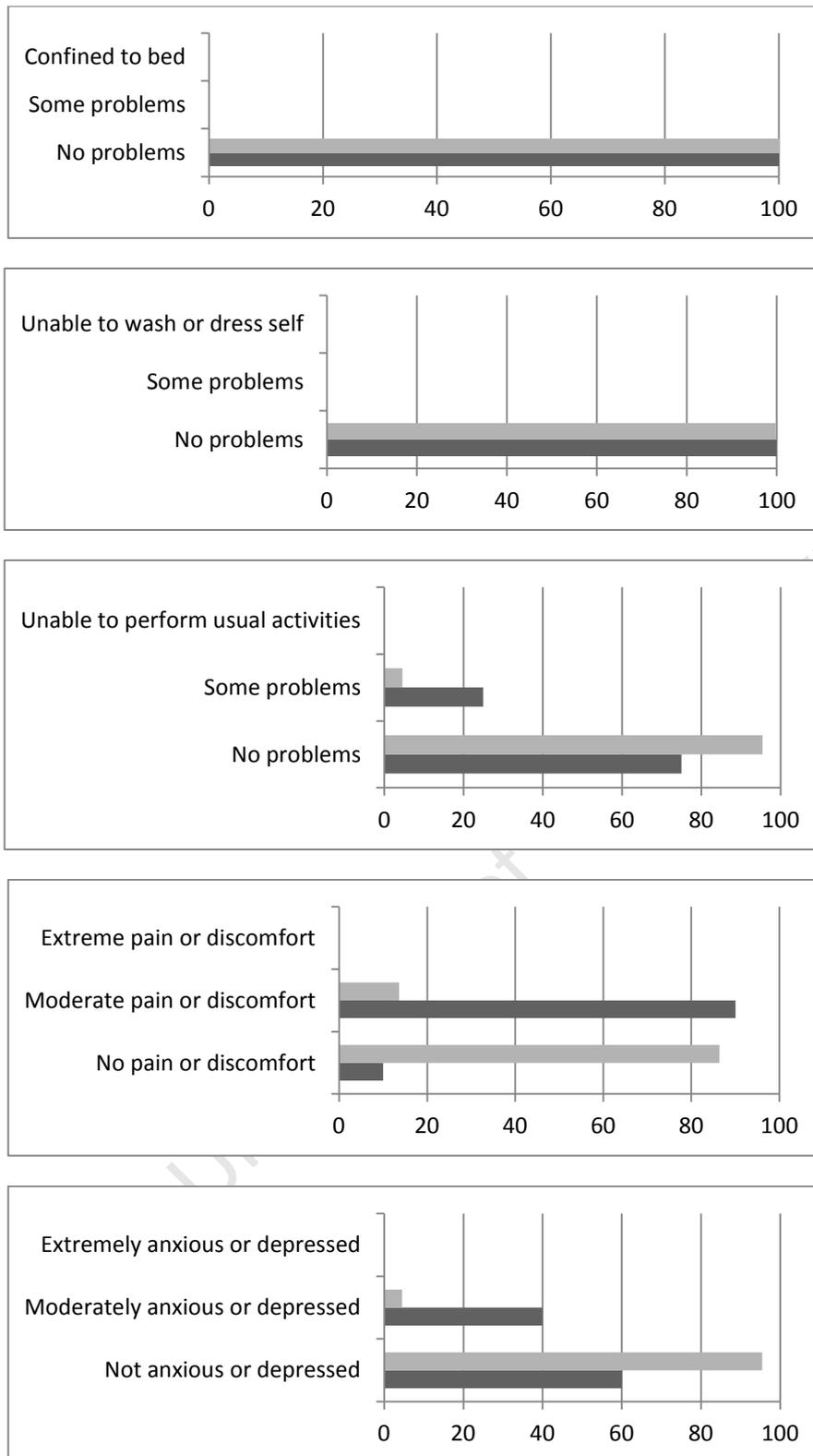
The HRQoL of participants in the case and control groups are presented in Table 4-4.

Table 4-4: Health related quality of life reported on the EQ-5D (N = 42)

EQ-5D	Sample (N = 42)		Pain group (n = 20)		No pain group (n = 22)		Test statistic	p-value
	Mean ± SD	Frequency (%)	Mean ± SD	Frequency (%)	Mean ± SD	Frequency (%)		
State of Health VAS	70.35 ± 10.91		60.60 ± 20.11*		80.02 ± 10.44*		$U = 129.50$	0.02
Mobility								
No problems		100.00		100.00		100.00		
Some problems		0.0		0.0		0.0		
Confined to bed		0.0		0.0		0.0		
Self-Care								
No problems		100.00		100.00		100.00		
Some problems		0.0		0.0		0.0		
Unable to wash or dress self		0.0		0.0		0.0		
Usual Activities							$\chi^2 = 3.58$	0.06
No problems		85.71		75.00		95.45		
Some problems		14.29		25.00		4.55		
Unable to perform		0.0		0.0		0.0		
Pain/Discomfort							$\chi^2 = 24.44$	p < 0.01
No pain or discomfort		50.00		10.00*		86.36*		
Moderate pain or discomfort		50.00		90.00*		13.64*		
Extreme pain or discomfort		0.0		0.0		0.0		
Anxiety/Depression							$\chi^2 = 7.82$	0.05
Not anxious or depressed		78.57		60.00*		95.46*		
Moderately anxious or depressed		21.43		40.00*		4.55*		
Extremely anxious or depressed		0.0		0.0		0.0		

Self-perceived state of health on the EQ-5D is measured between 0 (“*worst imaginable state of health*”) and 100 (“*best imaginable state of health*”). State of health VAS was significantly lower in the pain group (60.60 ± 20.11), compared to the no pain group (80.02 ± 10.44) ($U = 129.50$; $p = 0.02$). Further, there was a significant difference between groups in the category relating to pain, with 90% of the pain group reporting moderate pain/discomfort compared to only 13.64% of the no pain group ($\chi^2 = 24.44$; $p < 0.01$). In addition, levels of anxiety and depression were significantly different between groups, with 40% of the pain group reporting feeling moderately anxious or depressed, compared to 4.55% of the no pain group ($\chi^2 = 7.82$; $p = 0.05$). The total ordinal scale variables for the EQ-5D are presented below (Figure 4-1).

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Pain group in dark grey and no pain group in light grey

Figure 4-1: Health related quality of life as measured on the EQ-5D (N = 42)

4.6 Surface EMG activity

Surface EMG data were normalised using the respective muscle's MVC (Section 3.5, p. 81). The normalised activity levels for the right (R) and left (L) masseter and CE muscles at rest and during light teeth contact are presented in Table 4-5 and in Table 4-6, respectively. There were no significant differences in L or R masseter and CE sEMG activity either at rest (Table 4-5) or during light teeth contact (Table 4-6) between groups.

Table 4-5: Surface EMG data of masseter and CE at rest (N = 42)

	Sample (N = 42)	Pain group (n = 20)	No pain group (n = 22)	Test statistic	p-value
Average sEMG ($\mu\text{V/s}$):	Mean \pm SD	Mean \pm SD	Mean \pm SD		
At Rest:					
R masseter (0-5 seconds)	5.03 \pm 4.62	5.36 \pm 4.69	4.73 \pm 4.64	$U = 194.00$	0.52
R masseter (6-10 seconds)	4.97 \pm 4.63	5.28 \pm 4.66	4.68 \pm 4.69	$U = 189.00$	0.45
L masseter (0-5 seconds)	4.26 \pm 4.53	4.43 \pm 3.71	4.10 \pm 5.25	$U = 177.00$	0.29
L masseter (6-10 seconds)	4.13 \pm 4.18	4.31 \pm 3.65	3.96 \pm 4.70	$U = 183.00$	0.36
R CE (0-5 seconds)	14.80 \pm 10.35	14.85 \pm 7.36	14.75 \pm 12.65	$U = 191.00$	0.48
R CE (6-10 seconds)	14.83 \pm 10.37	14.90 \pm 7.51	14.77 \pm 12.61	$U = 196.00$	0.56
L CE (0-5 seconds)	16.31 \pm 13.25	15.43 \pm 6.88	17.12 \pm 17.28	$U = 183.00$	0.36
L CE (6-10 seconds)	16.24 \pm 13.18	15.40 \pm 6.83	16.99 \pm 17.19	$U = 180.00$	0.32

Table 4-6: Surface EMG data of masseter and CE during light teeth contact (N = 42)

	Sample (N = 42)	Pain group (n = 20)	No pain group (n = 22)	Test statistic	p-value
Average sEMG ($\mu\text{V/s}$):	Mean \pm SD	Mean \pm SD	Mean \pm SD		
Light teeth contact					
R masseter (0-5 seconds)	5.53 \pm 4.90	5.64 \pm 4.86	5.42 \pm 5.05	$U = 204.00$	0.70
R masseter (6-10 seconds)	5.51 \pm 4.81	5.58 \pm 4.81	5.45 \pm 4.92	$U = 208.00$	0.77
L masseter (0-5 seconds)	4.56 \pm 4.16	4.64 \pm 3.61	4.49 \pm 4.69	$U = 196.00$	0.56
L masseter (6-10 seconds)	4.50 \pm 4.09	4.56 \pm 3.54	4.45 \pm 4.62	$U = 200.00$	0.63
R CE (0-5 seconds)	14.64 \pm 10.14	14.08 \pm 7.00	15.14 \pm 12.49	$U = 202.00$	0.66
R CE (6-10 seconds)	14.70 \pm 10.20	14.01 \pm 7.00	15.32 \pm 12.58	$U = 205.00$	0.72
L CE (0-5 seconds)	15.89 \pm 11.91	14.88 \pm 6.02	16.81 \pm 15.57	$U = 179.00$	0.31
L CE (6-10 seconds)	15.90 \pm 11.95	14.60 \pm 5.83	17.09 \pm 15.65	$U = 189.00$	0.45

4.6.1 Rate of change in cervico-mandibular sEMG activity during light clench

Rate of change of sEMG activity was calculated as a percentage change. Descriptive statistics of the rate of change in the L and R masseter muscles over a 10 second period of posterior tooth contact (light clench) for the total sample and per group are presented in Table 4-7 below.

Table 4-7: Rate of change in masseter and CE sEMG activity during light clench

	Sample (N = 42)	Pain group (n = 20)	No pain group (n = 22)
Rate of % change in sEMG	Mean ± SD	Mean ± SD	Mean ± SD
<i>R mass Rate of change over 10 s</i>	100.42 ± 7.62	97.65 ± 3.24	102.93 ± 9.49
<i>L mass Rate of change over 10 s</i>	99.13 ± 5.42	98.76 ± 5.95	99.46 ± 5.01
<i>R CE Rate of change over 10 s</i>	100.08 ± 3.05	99.44 ± 3.13	100.67 ± 2.93
<i>L CE Rate of change over 10 s</i>	100.18 ± 5.58	98.57 ± 4.90	101.64 ± 5.86

There were no significant differences between groups for the rate of change over a 10 second period of posterior tooth contact (light clench) in the R or L masseter muscles using Man-Whitney U tests. Similarly, there were no significant differences between groups for the rate of change over time in the R or L CE muscles during 10 seconds of light clench using Man-Whitney U. The data may be interpreted as values less than 100 showing a decrease in muscular activity over the 10 seconds.

Correspondingly, values greater than 100 indicated an increase in activity over the 10 second recording period. There were no values for the chronic cervical pain group greater than 100, indicating a rate of fatigue in the R and L CE and R and L masseter muscle during the activity of light clench. In contrast, all of the cervico-mandibular muscles increased in activity over time for the total sample and no pain group, with the exception of the L masseter.

The next section will examine associations between the variables of cervical disability and pain, occupational and leisure activities, and perceived health status.

4.7 Relationships between the biopsychosocial variables

4.7.1 Cervical disability and pain

There was a strong positive correlation between the NDI and pain severity score from the BPI for the total sample ($Rho = 0.80$; $p < 0.05$). When the pain and no pain groups were analysed separately, there was a strong positive correlation between variables in the pain group ($Rho = 0.72$; $p < 0.05$), whereas the no pain group had a low to moderate positive correlation ($Rho = 0.50$; $p < 0.05$).

4.7.2 Cervical disability and activities

There was no significant correlation between NDI and total sitting hours per week for the total sample, or for the pain group. There was a weak positive correlation between NDI and total sitting hours per week isolated to the no pain group ($Rho = 0.39$; $p < 0.05$). When comparing the pain severity score from the BPI versus total sitting hours, there was no significant relationship observed for the total sample, or for the pain group. In the no pain group there was a weak positive correlation between pain severity and total number of hours spent sitting per week ($Rho = 0.43$; $p < 0.05$).

No relationship was found between NDI and total number of hours spent doing sports per week for the total sample, or for the pain group. However, there was a weak negative correlation between NDI and total number of hours spent doing sports per week for the no pain group ($Rho = -0.35$; $p < 0.05$). Further, no relationship was found between pain severity and total number of hours spent doing sports per week for the total sample, pain, or no pain groups.

4.7.3 Cervical disability and health related quality of life

i. Health Status

The relationship between NDI and state of health VAS revealed a weak negative Spearman correlation of $Rho = -0.35$ ($p < 0.05$) for the total sample. However, there was no such association between NDI and state of health VAS with respect to the pain and no pain groups. These findings may be interpreted as higher levels of cervical disability to be associated with lower levels of self-perceived health status within the total sample, yet not per group. In addition, there were no significant correlations between the pain severity score from the BPI and state of health VAS for the total sample, pain, or no pain group.

As previously mentioned, sEMG has played an important role in the assessment of muscle dysfunction in patients with chronic MSC in general (85,86,130) (Section titled Muscle activity, p. 24). Further, motor control strategies to nociception in the cervical area (85,86,109,110,116-118,126,131,132) remain unpredictable (9). In lieu of this, the relationship between cervical disability and cervico-mandibular sEMG was explored. As there were no significant differences between the group with and without chronic cervical pain in the respective 10 second time measures of sEMG at rest [Table 4-5, p. 95] and during light teeth clench [Table 4-6, p. 95] (28,29), the potential relationship between cervical disability and the resting sEMG activity was explored. The findings are presented below.

4.8 Relationships between chronic cervical MSC and resting sEMG

Results of the Spearman correlation tests between the variables of cervical disability and pain, and R and L masseter and CE muscle activity levels at rest are presented below.

4.8.1 Cervical disability and resting sEMG

There were no significant relationships between NDI and resting R and L masseter sEMG activity for the total sample, pain, or no pain group.

Similarly, no significant relationships were found between NDI and resting R and L CE sEMG activity levels for the total sample, pain, or no pain group.

4.8.2 Pain and resting sEMG

i. Pain severity

There was a moderate positive correlation between the pain severity score from the BPI and the R CE for the no pain group only ($Rho = 0.51$; $p < 0.05$). These results indicate greater levels of pain in the no pain control group (minor day-to-day discomfort unrelated to cervical pain) to be associated with higher levels of resting R CE muscle activity (Figure 4-2). The removal of the outlier (case 15) did not affect the relationship.

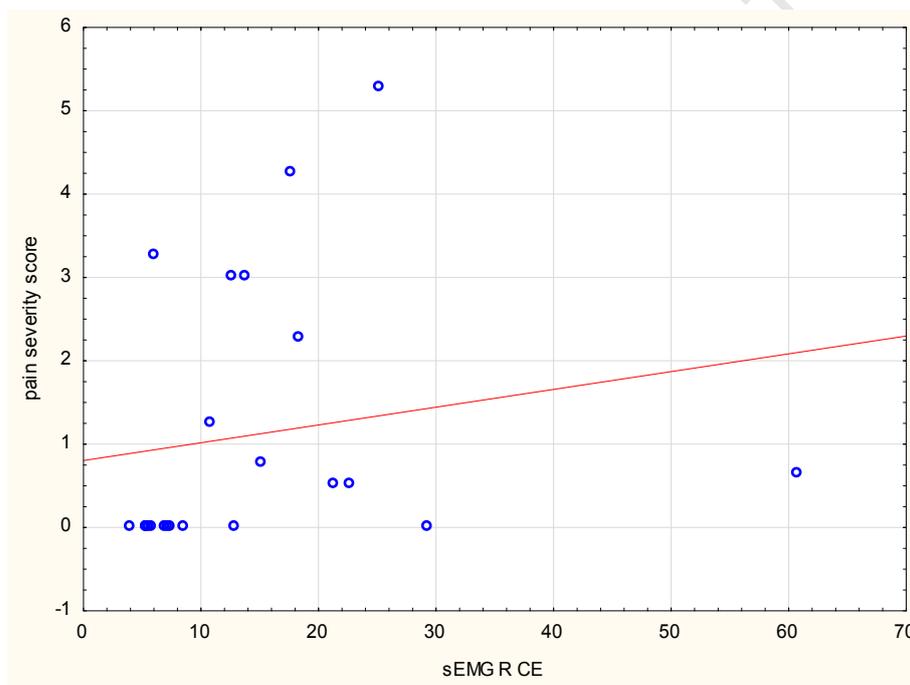


Figure 4-2: Relationship between pain severity score from the BPI and R CE resting activity in the no pain group

4.9 Daytime parafunctional teeth clench as a grouping variable

Following the identification of differences in daytime teeth clenching habits between the group with and without chronic cervical pain, the variable of daytime teeth clenching was used as a grouping variable to explore for differences in scores on the NDI, pain and HRQoL. A summary is presented in Table 4-8.

Table 4-8: Daytime teeth clenching as a grouping variable (N = 42)

Instruments	Clench No N = 29		Clench Yes N = 13		Test statistic	p- value
	Mean \pm SD	Frequency (%)	Mean \pm SD	Frequency (%)		
<i>Cervical Disability (NDI)</i>	5.31 \pm 5.59		8.46 \pm 5.32		$U = -104.5$	0.02
<i>Pain</i>	2.19 \pm 2.07		2.92 \pm 2.09		$U = 144$	0.23
<i>HRQoL</i>						
State of health VAS	7.56 \pm 1.91		6.87 \pm 1.91		$U = 146$	0.25
No Pain/discomfort		62.1		23.1	$\chi^2 = 5.46$	0.02
Not anxious or depressed		89.7		53.8	$\chi^2 = 6.84$	< 0.01
<i>sEMG</i>						
R masseter (0-5 seconds)	4.82 \pm 4.82		5.48 \pm 4.30		$U = 152$	0.33
R masseter (6-10 seconds)	4.76 \pm 4.80		5.42 \pm 4.35		$U = 151$	0.31
L masseter (0-5 seconds)	3.92 \pm 3.48		5.02 \pm 6.39		$U = 171$	0.64
L masseter (6-10 seconds)	3.86 \pm 3.44		4.73 \pm 5.62		$U = 173$	0.68
R CE (0-5 seconds)	15.29 \pm 11.47		13.70 \pm 7.57		$U = 181$	0.85
R CE (6-10 seconds)	15.45 \pm 11.51		13.45 \pm 7.43		$U = 175$	0.72
L CE (0-5 seconds)	15.68 \pm 10.25		17.73 \pm 18.75		$U = 188$	1.00
L CE (6-10 seconds)	15.62 \pm 10.27		17.60 \pm 18.55		$U = 188$	1.00

4.9.1 Clenching and cervical disability

There were significant differences in the level of cervical disability between those reporting teeth clenching and those who did not ($U = -104.5$; $p = 0.02$). This may be interpreted as significantly worse scores on the NDI arising in participants reporting clenching (Table 4-8).

4.9.2 Clenching and pain

There were no significant differences in the pain severity score from the BPI when analysed by the presence of clenching for the total sample ($U = 144$; $p = 0.23$) (Table 4-8).

4.9.3 Clenching and health related quality of life

i. Health status

There were no significant differences in the perceived state of health of participants when analysed by the presence of clenching ($U = 146$; $p = 0.25$) (Table 4-8).

ii. Anxiety/depression

Chi-squared tests were used to measure differences in the subgroups of the EQ-5D between those reporting and those not reporting teeth clenching habits. Using teeth clenching as the grouping variable, significant differences between groups were observed in the pain/discomfort subgroup index of the EQ-5D ($\chi^2 = 5.46$; $p = 0.02$) and in levels of anxiety/depression ($\chi^2 = 6.84$; $p < 0.01$) (Table 4-8).

4.9.4 Clenching and resting sEMG

There was no significant difference in the resting sEMG activity in the cervico-mandibular muscles when analysed by the presence of clenching (Table 4-8).

4.10 Health related quality of life as a grouping variable

The sub-section of the EQ-5D on anxiety/depression was used as a grouping variable for further analysis following identification of differences in the cases and controls for this item (Section 4.5, p. 91). A summary is presented in Table 4-9.

Table 4-9: Anxiety/depression as a grouping variable (N = 42)

Instruments	Anxiety No N = 33		Anxiety Yes N = 9		Test statistic	p- value
	Mean ± SD	Frequency	Mean ± SD	Frequency		
Cervical Disability (NDI)	5.06 ± 5.02		10.78 ± 5.74		<i>U</i> = 58	0.01
Pain	1.92 ± 1.95		4.22 ± 1.50		<i>U</i> = 53.5	< 0.01
HRQoL						
State of health VAS	7.82 ± 1.46		5.59 ± 2.40		<i>U</i> = 62	0.01
Reporting daytime teeth clenching		21.21		66.7	$\chi^2 = 6.84$	< 0.01
sEMG						
R masseter (0-5 seconds)	4.98 ± 4.92		5.20 ± 3.54		<i>U</i> = 118	0.36
R masseter (6-10 seconds)	4.92 ± 4.92		5.14 ± 3.59		<i>U</i> = 121	0.41
L masseter (0-5 seconds)	4.50 ± 4.88		3.36 ± 2.94		<i>U</i> = 136	0.71
L masseter (6-10 seconds)	4.35 ± 4.48		3.31 ± 2.91		<i>U</i> = 134	0.67
R CE (0-5 seconds)	14.28 ± 10.66		16.68 ± 9.44		<i>U</i> = 122	0.43
R CE (6-10 seconds)	14.35 ± 10.70		16.59 ± 9.44		<i>U</i> = 119	0.37
L CE (0-5 seconds)	17.30 ± 14.67		12.68 ± 4.56		<i>U</i> = 133	0.65
L CE (6-10 seconds)	17.23 ± 14.56		12.58 ± 4.80		<i>U</i> = 127	0.52

i. Anxiety/depression and cervical disability

There were significant differences in the level of cervical disability between those reporting anxiety/ depression and those who did not (*U* = 58; *p* = 0.01) (Table 4-9).

This may be interpreted as significantly worse scores on the NDI arising in participants reporting anxiety/depression.

ii. Anxiety/depression and pain

Similarly, there were significant differences in the severity of chronic cervical pain between those who reported anxiety/depression and those who did not ($U = 54$; $p < 0.01$). These findings infer that significantly more severe pain occurred in participants reporting anxiety/depression (Table 4-9).

iii. Anxiety/depression and clenching

There were significant differences in the presence of teeth clenching in those who reported anxiety/depression compared to those who did not report anxiety/depression ($X^2 = 6.84$; $p = 0.01$) (Table 4-9).

iv. Anxiety/depression and resting sEMG

No significant relationships were observed between levels of anxiety/depression and masseter or CE sEMG activity at rest (Table 4-9).

4.11 Summary of results

This chapter has presented the socio-demographic and biopsychosocial findings of a sample of female office workers with and without chronic cervical MSC. Further, the findings have provided the background for comparison between groups, and therefore the understanding of potential mechanisms and factors that may contribute to chronic cervical MSC.

The first section of the results revealed that there were no significant differences in the socio-demographic profile of the pain and no pain group. Significant differences were observed between groups for pain, presence of daytime teeth clenching habit, and HRQoL (perceived health status and the EQ-5D subgroup of pain/discomfort and anxiety/depression) due to chronic cervical pain. No differences were observed in sEMG activity of the cervico-mandibular muscles at rest or during light teeth clenching between those with and without chronic cervical pain.

Relationships in those with pain and those without pain between chronic cervical MSC and disability, pain, frequency of occupational and leisure activities, HRQoL (state of health), and sEMG were performed. There was only a strong positive correlation between cervical disability and pain for the total sample ($Rho = 0.80$; $p < 0.05$), pain ($Rho = 0.72$; $p < 0.05$), and no pain group ($Rho = 0.50$; $p < 0.05$), and a negative correlation between cervical disability and perceived health status for the total sample ($Rho = -0.35$; $p < 0.05$), but not per group. Lastly, there was no significant relationship observed between cervical disability and resting R and L masseter and R and L CE activity for the total sample, pain and no pain group. Therefore, there did not appear to be a difference in cervical disability based on cervico-mandibular sEMG findings.

Secondary analysis revealed that participants who reported teeth clenching also reported higher levels of cervical disability ($U = -104.5$; $p = 0.02$), higher levels of pain and discomfort on the EQ-5D index ($X^2 = 5.46$; $p = 0.02$), and higher levels of anxiety/depression ($X^2 = 6.84$; $p = 0.01$) than those who did not report teeth clenching.

Further secondary analysis revealed that participants who reported anxiety/depression also reported higher levels of cervical disability ($U = 58$; $p = 0.01$), higher levels of pain and discomfort on the EQ-5D index ($U = 54$; $p < 0.01$), a lower perceived state of health ($U = 62$; $p = 0.01$), and a higher prevalence of teeth clenching habits than those who did not report anxiety/depression. However, neither the presence or absence of teeth clenching or anxiety/depression appeared to influence the resting sEMG activity levels in the cervico-mandibular muscles. Therefore, there did not appear to be a difference in presence of teeth clenching or anxiety/depression based on cervico-mandibular sEMG findings.

CHAPTER 5: DISCUSSION

The aim of this study was to explore cervico-mandibular sEMG activity in female office workers with chronic cervical MSC, and the relationship between chronic cervical pain and disability and sEMG. The results have provided additional information on the contributory role of physiological and psychosocial factors in chronic cervical MSC in the study's female participants.

The findings of this study are in agreement with previous literature, which suggests that there are socio-demographic and biopsychosocial factors associated with chronic cervical MSC (1,3,5-8,119,120). The first section of the discussion describes the socio-demographic profile of the sample. This description provides a background for the discussion of biopsychosocial characteristics, such as the relationship between chronic pain and disability, and the relationships between chronic cervical MSC and potential contributory factors of occupational and leisure-related sporting activities, teeth clenching habits, and HRQoL.

5.1 Socio-demographic characteristics

The socio-demographic profile for the total sample of adult females within the workplace was documented in Table 4-1 (p. 89). In this study, there were no differences between groups in age, BMI, occupation, physical and leisure activity levels, hand dominance, and ethnic group. The total sample had limited socio-demographic variance as a result of the method of recruitment and type of sample generated which consisted of university employees and students. One may argue that the sample was indeed matched with regard to socio-demographic variables. A broader range of socio-economic and socio-demographic variability may have led to a varying set of study results.

The average age for the total sample was just under 30 years of age. This average figure is higher than the average age of a student, probably elevated by the equal ratio of student:staff/faculty participation per group. Age has been identified as a factor contributing to spinal degeneration and cervical symptoms (3,91-94).

Similar studies to this that employed strict exclusion criteria for other chronic MSC (for example, lower back pain and TMPDS) were useful in comparing the relationships that may exist between chronic cervical disability and the socio-demographic variables of age, BMI, and occupational activities (12,119,120). Two successive studies by Johnston et al (119,120) found a linear relationship between self-reported chronic cervical pain and cervical disability. Further, their sample was categorised into employed groups with no pain, mild disability (NDI = 9 to 29) and moderate disability (NDI \geq 30), and a control group of unemployed participants. Although there was minor variation in the pain instrument used between Johnston and colleagues (119,120) and this study, namely the VAS and not the pain severity score from the BPI, this was not deemed to unduly limit comparison between the studies. Therefore, relevant comparisons between their “*mild disability*” group and this study’s case group could be made. Results in the present study and in the study by Johnston et al (119,120) have shown a lack of significant difference in age between participants with and without chronic cervical MSC. An explanation for this may be that the significant link between age and load-bearing degenerative changes appear to become prevalent at a slightly higher average age group to the present sample and that of Johnston and colleagues (from the third to the sixth decade of life) (3,91-94,119). However, it must be noted that the sample in the present study had a narrow age range, which limits potential conclusions regarding age and presence of symptoms based on these data.

Further, the average BMI for the total sample was 24 kg/m². According to the Centre for Disease Control (252), the present study’s total sample fell within the “*normal*” BMI category, although the figure approached the “*overweight*” category. Further, the average BMI of 24 kg/m² was comparable to a typically “*healthy*” middle-aged South African population sample (151). There were no significant differences observed in BMI between the current study’s pain and no pain groups, as with the findings of Johnston and colleagues (119,120). Yates (41) found that the sample population of South African adult females seeking treatment for low back pain presented with BMI figures ranging from “*normal*” to “*obese*” categories. Therefore, one could argue that this study’s pain group profile with chronic cervical pain and disability fell into a fairly normal healthy BMI category.

The total sample performed an average of approximately 26 h/wk of sedentary office work and approximately 1h/wk of leisure-related physical activity. Possible reasons for the relatively low levels of leisure-related physical activity observed in the current study were not explored. Examples of limitations of physical activity may have included work schedules, personal circumstances, or pain and discomfort associated with chronic cervical MSC. The weekly frequency of prolonged seated positions in both the pain and no pain group was recorded at 26 h/wk hours per week, approximately 5 h/day. This “dose” is greater than the 4 h/day of sedentary sitting regarded as sufficient to result in the development of fatigue and cervical MSC in adults (6-8,57,109,110). Yet, there were not significant differences between groups for frequency of sedentary sitting or physical activity. This was somewhat surprising, as sedentary computer work is considered a risk factor for chronic cervical MSC (6,7,57,109,110). As mentioned earlier, the total sample was well-matched in their socio-demographic profile, including work description. Subsequently, sampling over a broader socio-demographic profile may have exposed different results to the present study findings. Nevertheless, Johnston et al (119,120) reported similar findings to the study undertaken here, and were unable to determine any differences in total sitting frequency or sporting frequency in those presenting with and without chronic cervical MSC.

The total sample was predominantly right hand dominant (greater than 95%). Ninety five percent of the pain group and 95% of the no pain group indicated they were R hand dominant. Therefore, one could infer similar well-matched daily computer-based and office-related upper limb activities and muscle usage for those with and without chronic cervical MSC. There were no differences between groups in ethnicity. Previous studies have identified that inter-ethnic [and intra-ethnic] population groups may have differing facial morphology and sEMG cervico-mandibular activity (26,31,177). However, as the two groups were well matched in terms of ethnicity, this socio-demographic variable probably had little to no influence on the results of this study.

In this study, age and BMI were equivalent across the pain and no pain group, therefore eliminating a confounding factor. Further, groups were matched according to gender and occupation, factors which are known to contribute to chronic cervical MSC (6-8,57,88,89,109,125). The matching of groups according to these variables allowed for the exploration of further factors that may contribute to chronic cervical MSC, such as biopsychosocial factors.

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5.2 Biopsychosocial characteristics

5.2.1 Cervical disability and pain

The NDI (on a score of 0 to 50) for the total sample was 6.29 ± 5.64 , with significant differences observed between the “*mild*” cervical disability pain group (11.00 ± 4.72) and the no pain group (2.00 ± 1.20) (Table 4-2, p. 90). There was concurrent validity, confirming the study’s two pain instruments (233,238) (Section 4.3, p. 90). The pain severity score from the BPI for the total sample was low, at 2.41 ± 2.08 , with significant differences observed between groups.

5.2.2 Teeth clenching

Of the total sample population in this study, 31% reported the parafunctional habit of daytime teeth clenching. This is comparable to findings from previous studies that used samples of a similar age group, but of mixed gender (23,183). Further, the pain group showed a significantly greater prevalence of the daytime teeth clenching habit compared to the no pain group. The prevalence of daytime teeth clenching in the pain group was 50%, while it was limited to approximately 14% in the no pain group. There is a lack of evidence for the prevalence of daytime teeth clenching among office workers with chronic cervical MSC.

Teeth clenching may be an indicator of other unrelated psychosocial factors (23,190). The presence of teeth clenching has been documented in people reporting TMPDS as well as in healthy individuals (85,86,182,191,192). TMPDS and to a lesser extent non-TMPDS sufferers have presented with elevated sEMG activity levels of the masseter at rest or pre-task due to the parafunctional habit of teeth clenching. Instances of pre-task experimental stressors have been those of strenuous rowing sessions, stressful competitions, or fixed-time office tasks, as well as psychophysiological “stressors” (85,86,182,192). However, there are limitations associated with the current literature on the effects of teeth clenching. Many investigations that have examined the effects of experimental teeth clenching on the isolated or combined effects of the masseter or cervical muscle sEMG values have not described normalisation procedures for sEMG data (26,29,30,182). The absence of normalisation of sEMG data reduces reliability and reproducibility, thus limiting the interpretation of data (201,202).

5.2.3 Health related quality of life

The sub-section of the EQ-5D on the state of health VAS reported the total sample score to be over 70 (on a score of 0 to 100) (Table 4-4, p.92). Further, for the total sample, there were few subgroup limitations in the EQ-5D concerning HRQoL: mobility (no limitations), self-care (none), 14% experienced minimal interference when conducting their usual activities, 50% reported no pain/discomfort while 50% reported moderate levels, 79% reported no anxiety/depression while the remaining 21% reported moderate levels. When comparing groups, the average perceived state of health VAS for the pain group was significantly lower than for the no pain group (61 versus 80). An example of a study using a mixed-gender adult sample with low back pain reported state of health VAS to be 63 ± 20 , with only 4% experiencing no pain/discomfort (41). This figure provides one with an idea of HRQoL in the presence of a chronic disability, such as low back pain. However, chronic cervical disorders, rather than lower back problems, are generally associated with lower disability (3,4). Therefore, the present pain group’s level of disability and HRQoL may be considered as a fair representation of those with cervical pain.

In addition to significant differences between groups for the EQ-5D sub-section on health status, there were significantly higher levels in the pain group for the EQ-5D subgroup indices of pain/discomfort and anxiety/depression. This is in accordance with previous studies that reported greater impairments in HRQoL and higher states of anxiety in those with chronic cervical disorders compared to no pain control participants (15,163). Literature has alluded to these psychological factors as predictors of the persistence of chronic cervical MSC (47,160,161,165), rather than responses to the experience of pain (2). The precise mechanisms behind depression in particular and chronic cervical MSC remain unclear (3,46,59,157,163). In addition, the cross-sectional design of the present study could not make inferences as to cause or effect mechanisms in chronic cervical MSC.

5.2.4 Surface EMG

As previously mentioned (Section on Muscle activity, p. 24), sEMG levels of resting activity, distribution of area of activity, and firing pattern activity may reveal the extent of involvement or mechanisms behind chronic cervical pain (86,253). The present study explored the extent of muscle dysfunction and motor strategies in those with chronic cervical MSC (147,148,245), extending from the cervical musculature through the temporomandibular area.

There were no significant differences between groups in bilateral masseter or CE sEMG activity at rest (Table 4-5, p. 95). Data from the BPI's body chart suggested that the average area of chronic posterior cervical pain present in the pain group was mainly bilateral. Yet, resting sEMG activity levels appeared uninfluenced by the presence of cervical pain-related disability, area of bilateral pain, or presence of light teeth clenching. The present study findings on the lack of difference in the resting sEMG activity of the masseter muscles are not comparable to any previous research, as earlier studies have only used healthy sample groups for various correlation purposes (26-30). Further, the present study findings on the lack of difference in the resting sEMG activity of the CE muscles between pain and no pain groups concur with previous cervical investigations (109,126). However, the present study results also appear to conflict with previous research which showed an increase in resting sEMG CE activity in the presence of cervical pain-related disability (7,112,119,120), relative to area of pain (110,144).

Important differences between the previous investigations and the current study findings will be described below, and should assist in accounting for the conflicting results.

Additional results of this study showed no differences in cervico-mandibular sEMG activity between pain and no pain groups at rest and during light clench (Table 4-6, p. 95). Furthermore, there were no significant differences found between groups for cervico-mandibular sEMG rate of change in activity over the 10 second period of light clench. The sEMG results may conflict with previous research on resting sEMG (7,112,119,120) and light clenching sEMG (5,7,26,30,112,119,120). A number of important differences between the previous investigations and the current study findings may provide an explanation for the conflicting results.

There are fewer studies performed on the CE muscle group in the presence of chronic cervical pain (7,112,116,117,119,120,125,134,244,245) in contrast to the numerous cross-sectional studies using the UT, SCM, and anterior scalene cervical muscles during office tasks (113,116,117,134,204,244). It is recognised that the strict exclusion criteria set by the present study may have potentially reduced the overall severity of cervical disability of its participants to mild disability. Therefore, higher levels of disability may have led to greater differences between the pain and no pain groups in resting sEMG of the CE in isolation and of the cervico-mandibular muscles as a whole. Further explanations for the conflicting results between previous investigations and the current study may lie in the differences in sampling. The present study used participants with chronic cervical MSC and healthy participants on which to base the sEMG results, whereas previous studies have only used samples of healthy individuals to explore masseter and CE activity levels (26-30). In addition, many investigations did not employ normalisation processes for their sEMG study data (26,29,30). Therefore these findings should be interpreted with caution (201,202).

Lastly, recording of sEMG for longer than the 10 seconds used in the present study may have provided more information on rate of fatigue in the cervico-mandibular muscles of the pain and no pain groups (85,86,131). The present study chose to use 10 second recording windows for resting levels and activity levels during light clenching, according to previous literature on cervico-mandibular activity (28,29).

However, investigations by Flor (85,131) and De Sade (86) have looked extensively at psychophysiological responses to internal and external stressors and stimuli, detecting functional reorganisation in the motor system (through sEMG) and somatosensory cortex reorganisation. Their procedures for obtaining sEMG resting levels included adaptation phases of 12 minutes, followed by 2 minute recordings (86). However, the data from De Sade (86) needs to be interpreted with caution, as it has not to date been published in a peer-reviewed journal.

Inter-relationships between cervical disability and the numerical values of pain, frequency of occupational and leisure-related activities, and the HRQoL sub-section of state of health VAS were explored, and are discussed below.

5.3 Relationships between the biopsychosocial variables

5.3.1 *Cervical disability and pain*

Literature has highlighted that the impact of cervical pain should be measured, among other factors, by its propensity to disable individuals (4). The BPI's condition-specific features allowed for this instrument to establish potential relationships between cervical disability, as measured with the NDI, and pain. In the present study, strong correlations existed between cervical pain and disability for the total sample and pain group, decreasing slightly in strength for the no pain group (Section 4.7.1, p. 97). However, there did not appear to be a difference in cervical disability based on cervico-mandibular sEMG findings (Table 4-5 and Table 4-6).

Hermann and Reese (87) found a moderate correlation between intensity of pain (as part of a group of impairments) and perceived degree of disability in their patients with chronic cervical pain ($Rho = 0.73$; $p < 0.01$). Chiu et al (61) also observed a moderate association in the pain-disability correlation ($Rho = 0.55$ to 0.63 ; $p < 0.01$). However, Hermann and Reese (87) used mixed gender hospital patient samples of chronic cervical patients, with higher levels of disability in comparison to the present study ($NDI > 30$). Furthermore, Chiu et al (61) did not employ the NDI questionnaire for correlative purposes with pain. Rather, the investigators used the NPQ, which has a similar structure and psychometric properties to the NDI, but has not been as extensively validated among different patient populations (215,216).

Therefore, although the findings of the pain-disability correlation from Hermann and Reese (87) and Chiu et al (61) were similar to the present study findings, the results should be compared with caution due to methodological differences between studies.

Further results from Hermann and Reese (87) and Chiu et al (61) compared the strength of the pain-disability relationship to time since onset of pain. Hermann and Reese (87) revealed that the pain-disability correlation was not influenced by time since onset of pain. This was according to investigations that employed three groups of acute, subacute, and chronic patient groups. In contrast, Chiu et al (61) found that the correlation between intensity of pain and perceived degree of disability increased with chronicity. Their results were based on groups that had inclusion criteria of greater than three months of pain duration. However, Chiu et al (61) provided an additional physiotherapy treatment intervention and recorded patient satisfaction, which strengthened their pain-disability correlation from $Rho = 0.55$ to $Rho = 0.63$ ($p < 0.01$). Both the physical and psychological aspects of the physiotherapy treatment and perception of improvement may have influenced their results. Yet chronicity does not necessarily imply an increase in pain or disability (9,62). Further, pain may precede disability, but it may not always lead to disability (44,62,63).

As was previously mentioned, the level of cervical impairment and disability is recognised to be influenced by the level of pain severity and duration of cervical symptoms (8,61). Ylinen et al (82) have revealed a high variability in individual impairment-disability. The investigators recruited a sample of female clerical employees, with an average NDI of 22 and a VAS of 58/100, with the objective of measuring cervical muscle strength and range of motion. Their results showed an insignificant association between the level of perceived NDI and passive range of motion (of flexion, extension, lateral flexion, rotation) or maximal isometric strength (flexion, extension, rotation). In contrast, the association between current pain and their variables of range of motion and maximal strength was strong. These findings suggest that pain plays a larger role in signs and symptoms of the cervical spine compared to perceived disability. However, a possible reason for high variability in individual impairment-disability presentation in their sample population, may have been due to potential inclusion of contributory pain hypersensitivity syndromes, such as TMD/TMPDS, creating sample heterogeneity (46,59,159,175).

For example, Falla et al (116) did not strictly exclude pain hypersensitivity syndromes such as TMD/TMPDS when investigating chronic cervical pain and disability. The sample population used by Falla and colleagues initially appeared to have similar levels of cervical disability to that of the current study. Their sample of chronic cervical sufferers had an average NDI of 10.9 ± 4.6 and a numerical rating scale for pain of 3.9 ± 2.4 . The investigators sought to measure altered patterns of sEMG activation during functional tasks isolated to the cervical flexor and UT muscle groups. As a result of the absence of strict exclusion criteria for other chronic MSC conditions, the results of sEMG activity for their case group should be compared or extrapolated across studies with caution. Furthermore, Falla and colleagues (116) observed that perceived levels of cervical disability, especially in circumstances of traumatic origin through WAD, have a strong association with elevated cervical sEMG activity levels (at baseline, during and post-task). This indicates their recognition of altered pain processing mechanisms relative to pain-related disability. However, the augmented sEMG activity in their case group may have been influenced by unreported co-morbidities.

5.3.2 Cervical disability and activities

There was no significant correlation between NDI and total sitting hours per week for the total sample or for the group with chronic cervical pain. There was a weak positive correlation between NDI and total sitting hours per week isolated to the no pain group (Section 4.7.2, p. 97). Similarly, there was a weak positive correlation between pain severity and total sitting hours per week isolated to the no pain group. Therefore, there appeared to be a stronger correlation between pain and total sitting hours per week, compared to NDI and total sitting hours, isolated only to the group without chronic cervical pain. These results emphasise that although pain may precede disability, it may not always lead to disability (44,62). As previously mentioned, factors of chronology and intensity of pain have been shown to influence the pain-disability correlation (8,61). Furthermore, the findings by Ylinen et al (82) suggested that pain may play a larger role in signs and symptoms of the cervical spine, and therefore its impact on activities, compared to perceived disability.

Potential reasons for the failure to display associations between “*dose*” of sedentary sitting and pain group symptomatology in the current study may lie in the mean low level of NDI in the pain group. Previous literature has highlighted the controversial relationship between postural cervical pain and workplace ergonomic-related postures (75). The present study findings sought to contribute to the debate (6-8,57,75,109,110) concerning the role of workplace ergonomic-related postures and muscle fatigue (due to physical exposure, duration and repetitiveness of movement) as true mechanisms behind occupation-type chronic cervical MSC. Similar findings were reported by Johnston et al (119,120), who used sample groups with no pain, mild cervical disability, and moderate disability. The investigators found no significant association between time spent with computer usage and level of chronic cervical pain and disability in their samples of case-control office workers.

In the current study, there were no significant relationships between NDI and total hours of leisure-related physical activity for the total sample or for the group with chronic cervical pain. There was a weak negative correlation between NDI and sporting activities for the no pain group. However, no significant relationship for the total sample or per group existed between pain and total hours of leisure-related physical activity. The absence of significant relationship between NDI scores and frequency of sporting activity should not minimise the potential role of health factors in the risk for developing chronic MSC. According to the literature, health status and perceived HRQoL may influence MSC through physical, mental, and social factors (40,41,47,62,67,153-155,160-163).

Naidoo and Coopoo (151) found that the prevalence of lower back MSC significantly correlated with a BMI greater than 30kg/m^2 , due to the lack of leisure-related physical activity. The investigators found high correlations between anthropometrical data of percentage body fat and BMI, and the overall risk to lower back pain. However, in the case of chronic cervical MSC, it cannot be assumed that an increase in BMI is predictive of chronic cervical MSC, as cause and effect mechanisms remain unclear (128,147,148). Yet studies have observed from baseline the preventative benefits of physical activity levels on the incidence of chronic cervical MSC (154). Further, studies have recorded the positive influences of leisure-related physical activity on recovery from work-related MSC and early recovery from vehicle trauma and WAD (1,155).

Secondly, Lobbezoo et al (163) and Pallegama et al (15) described the psychosocial risk factors of poor health on MSC. A reduced HRQoL may accompany higher states of stress, anxiety and depression. These factors have been recognised as significant predictors for the development of MSC, including chronic cervical MSC, as well as predictors for poor biological outcomes in the treatment and management of MSC (2,3,15,46,59,157,162,163).

Leisure-related sporting activity is a source of social interaction, and reductions in these activities and social interactions have been linked with maladaptive pain-related disability (62,67). It may be proposed that lower frequencies of leisure-related sporting activity are indirectly associated with cervical disability, through lower levels of HRQoL. Hence, leisure-related sporting activity may influence HRQoL, and therefore chronic cervical MSC problems, either directly or indirectly through physical, mental, and social factors.

5.3.3 Cervical disability and health related quality of life

i. Health status

The present study revealed that higher levels of cervical disability in the total sample were associated with lower levels of self-perceived health status (Section 4.7.3, p. 98). This negative linear relationship between NDI and state of health VAS was not seen per group, despite the significant differences in cervical disability and state of health that were observed per group (Section 4.5, p. 91). Subsequent correlations between severity of chronic cervical pain and state of health did not prove significant for the total sample or per group. Hence, one cannot exclude the possibility that additional aspects of pain or HRQoL (such as anxiety/depression) may have played a larger role in the state of health of the participants than the isolated variable of disability (15,163). However, the cross-sectional design of the study did not allow for inferences on cause or effect mechanisms regarding the relationship between cervical disability and perceived state of health.

Further pathophysiological mechanisms in chronic cervical MSC were explored by looking at the isolated physiological relationships between disability, pain, and sEMG motor activity at rest.

5.4 Relationships between chronic cervical MSC and resting sEMG

5.4.1 Cervical disability and sEMG

There were no significant relationships found for the total sample or per group between NDI and resting sEMG activity in the masseter and CE muscles respectively (Section 4.8.1, p. 98). Firstly, results on the relationship between cervical disability and resting sEMG masseter activity are not comparable to any previous research, as previous studies have only used healthy sample groups for various correlation purposes (26-30). Secondly, results in the present study on cervical disability and resting CE activity appear to conflict with previous research showing an increase in resting sEMG CE activity in the presence of cervical pain-related disability (7,112,119,120).

A possible reason for the lack of increase in resting sEMG CE activity for the present study's pain group may have been the mild average disability reported in this group, despite the average disability level being significantly higher than that of the no pain group. The use of higher levels of disability for the pain group may have led to varying results on the relationship between cervical disability and resting sEMG cervico-mandibular activity.

For instance, Falla et al (116) observed that the strength of association between perceived level of cervical disability and baseline levels of cervical sEMG activity were dependent on mechanisms of onset of cervical disability. Falla and colleagues compared somatosensory disturbances in their traumatic WAD, non-traumatic, and control groups to reveal that their WAD group had elevated baseline cervical muscle activity compared to the idiopathic cervical and control groups, due to an augmentation in CNS somatosensory disturbances and disability.

It appears that in the current study the presence of chronic cervical MSC may not be limited to a purely biomechanical representation of disability. Yet, it seems that these findings are at present inconclusive. Further analyses of the potential relationships between cervical disability and biopsychosocial factors are required in order to better understand the integrative action of the CNS and its role in chronic cervical MSC.

5.4.2 Pain and resting sEMG

There was a moderate positive correlation between pain severity and the resting sEMG activity in the R CE muscle for the control group (Figure 4-2, p. 99). The results indicated greater levels of pain in the control group (minor day-to-day discomfort unrelated to cervical pain) to be associated with higher levels of resting R CE muscle activity. There is wide variability in literature reported on the sensorimotor changes of the cervical muscles in the presence of pain (65,115,129,254).

Study results, dependent on study sample and design used (experimental animal pain studies, experimental human, or clinical pain research) have observed varying levels of cervical activity in the agonist, antagonist and synergist muscles at rest and during dynamic movements, in the presence of pain of acute and chronic pain (Section titled Muscle activity, p. 24). The present study findings appear to agree with those who report no difference in resting sEMG CE activity in the presence of cervical pain-related disability (109,126). However, the present study findings conflict with previous research showing either a decrease (109,118,126,254) or an increase in resting sEMG CE activity in the presence of cervical pain (7,112,119,120) (36,116), relative to area of pain (110,144). Possible explanations for the conflict in results are discussed below.

Firstly, time measures of greater than 10 seconds for the recording of sEMG may have led to varying results on the relationship between pain and resting sEMG CE activity (85,86,131). It is theorised that static/isometric muscle activation patterns at rest are associated with decreased periods of EMG amplitude-based motor variability, further linked with increases in tissue ischaemia and inflammation, contributing to muscle fatigue in chronic cervical MSC (109,113,114). Further motor strategies, increasing with chronicity, have been reported using sEMG, namely aspects of asymmetry of tension, symptom-specific reactivity to psychophysiological stressors, delayed return-to-baseline levels, and variations in firing patterns during dynamic movement (85,86,109,110,116-118,126,131,132). Therefore, short time periods of 10 seconds may limit detection of potential motor strategies, even at rest. For instance, De Sade (86) used 2 minute recording periods to obtain the resting levels of MSC-specific muscle groups. However, as mentioned earlier, the data from De Sade (86) needs to be interpreted with caution, as it has not to date been published in a peer-reviewed journal.

Furthermore, due to the cross-sectional design of the study one cannot speculate as to the causative mechanisms for the above-mentioned sEMG findings. Factors in addition to pain severity may have acted as potential contributory influences to the sEMG changes in the R CE muscle group (65,115,129,254). Probably due to the low to absent levels of pain in the no pain group (allocated to day-to-day aches that were not related to the cervical spine), right hand dominance may have played a stronger role on R CE-sEMG correlations than simple motor-pain interactions. Further confirmation of this appears in the present study's earlier findings (Section 5.2.4, p. 111), where differences in cervical pain severity did not appear to influence sEMG. Hence, the R CE-sEMG correlation isolated to the no pain group may be theorised to be due to hand dominance. In contrast, hand dominance has been shown to share a weaker relationship with sEMG activity levels compared to ipsilateral area of chronic pain and sEMG (110,144). This could be a factor contributing to the lack of association in the pain group.

In the current study, the lack of cervico-mandibular sEMG findings in relation to disability and pain have highlighted that complex pathophysiological mechanisms may not be limited to purely biomechanical influences. Hence, factors which were reported to be significantly different in those with and without chronic cervical MSC were explored as secondary analysis, and used as grouping variables. Firstly, the variable of daytime teeth clenching was used as a grouping variable to explore for differences in NDI, pain, HRQoL, and sEMG. This is discussed below in Section 5.5 (p. 123). Following this, HRQoL was employed as a grouping variable to explore differences in NDI, pain, presence of teeth clenching, and sEMG (Section 5.6, p. 127).

5.5 Daytime teeth clenching as a grouping variable

Refer to Table 4-8 (p. 100) for a summary on clenching as a grouping variable.

5.5.1 Clenching and cervical disability

There were significant differences in the level of cervical disability between those reporting teeth clenching and those who did not. Participants from the total sample reporting clenching had significantly worse scores on the NDI. Teeth clenching could be seen as an ongoing/repetitive peripheral nociceptor, influencing chronic cervical MSC through central sensitisation and pain summation (9). Yet, it seems that these findings are at present inconclusive. Further analyses of the biopsychosocial factors as independent grouping variables are required in order to better understand the integrative action of the CNS and its role in chronic cervical MSC.

5.5.2 Clenching and pain

In contrast to the above-mentioned findings on NDI and teeth clenching, there were no significant differences in pain severity (according to the BPI) when analysed by the presence of clenching. In other words, participants from the total sample reporting either the presence or absence of clenching reported similar levels of pain. As mentioned in the literature review (Section 2.5.4, p. 68), the BPI (233) appeared to be the most appropriate generic tool for measuring pain in the present study. As mentioned earlier, a study by Nicholson et al (191) reported that daytime teeth clenching was a fairly common response to psychophysiological stressors relating to office and competitive tasks. Further, it was reported that teeth clenching may or may not put one at risk of developing TMPDS or other/additional orofacial or cervical conditions (23,24,138). Therefore, teeth clenching does not appear to be isolated to factors of pain-related disability, and appears to be linked to lifestyle stressors as a parafunctional habit (23,190).

5.5.3 Clenching and health related quality of life

i. Health status

There were no significant differences recorded in the health status of participants when analysed by the presence of clenching. At first, the results of the present study on teeth clenching and related biopsychosocial factors appeared to conflict with those of previous research (15,163). However, on closer inspection, few studies have looked at perceived state of health as a separate sub-section within HRQoL. For instance, Pallegama et al (15) found that their matched mixed-gender samples of people reporting TMPDS (as a result of teeth clenching) and combined TMPDS/cervical disorders exhibited significantly higher states of anxiety than their control group. Further, the two case groups with isolated and combined TMPDS reported high levels of physical and psychological compromise. Factors of reduced HRQoL in general, high levels of anxiety, depression, sleep disorders, as well as co-morbidity and/or multiple pain sites (15,46,79,80,163) have been labelled as cause-or-effect mechanisms behind the associations between teeth clenching, TMPDS, and cervical disorders, though these mechanisms remain elusive (3,15,41,46,59,157,163).

ii. Anxiety/depression

Although there were no differences observed in health status VAS, there were significant differences in the pain/discomfort subgroup index of the EQ-5D and in levels of anxiety/depression observed between those reporting and those not reporting teeth clenching habits. Therefore, it appears that the presence of a teeth clenching habit may occur in the presence of anxiety/depression and pain. These findings concur with previous research using logistic regression analyses that showed frequent teeth clenching in a TMPDS-free sample population to be positively associated with severe stress experiences (OR = 5.00) (190). Further, results have shown the prevalence of bruxism to be significantly higher in middle-aged females employed in the tertiary sector, reporting high levels of stress (23,190). The current cross-sectional design of the study did not allow for inferences on cause or effect mechanisms regarding the relationship between teeth clenching and anxiety/depression. However, it appears more likely to observe the influences of anxiety/depression on clenching, rather than the inverse relationship.

5.5.4 Clenching and resting sEMG

In the current study, there were no significant differences in cervico-mandibular sEMG activity at rest between participants who clenched teeth and those who did not (Section 4.9.4, p. 101). These findings are discussed below, in correlation with previous studies that explored masseter (26-28) and CE (26,29,30) muscle activity levels during experimental teeth clenching. The masseter and CE muscle groups will be discussed separately below.

Firstly, in the current study the presence of parafunctional teeth clenching was not associated with increases in resting masseter muscle activity. Previous literature has highlighted the link between bruxism and TMPDS. However, the volunteers for the present study were specifically excluded if they had any signs of TMPDS making comparison with this literature redundant. There is consensus between the results of the present study and research identifying the presence of teeth clenching in healthy individuals (23,25,103,159,182,190,191). There is additional agreement with literature with regards to the presence of minimal levels of spontaneous muscular activity/resting tremor of the mandibular muscles in healthy individuals (85,207).

Secondly, with regards to the CE muscle group, the presence of the parafunctional habit of clenching was not associated with increases in resting CE muscle activity. As previously mentioned, experimental studies on cervico-mandibular activity have limited their study samples to healthy individuals (26-30). Therefore, their results cannot be generalised as a true representation of CE muscle activity in chronic cervical sufferers. Further, as mentioned earlier, the lack of sufficiently high NDI levels in the total sample of the present study may have potentially dampened the detection of differences in cervico-mandibular muscle activity in the presence of teeth clenching. Nevertheless, a purely biomedical relationship between teeth clenching and sEMG does not appear to exist.

The pathophysiological mechanisms underlying chronic cervical MSC are recognised to be complex and remain unclear (56). However, a few pertinent qualities of central sensitisation in the presence of chronic cervical MSC appear to have been brought to light in the present study. From the overall study results thus far, it would appear that biopsychosocial drivers may have played a more complex role than a linear relationship between sEMG motor output and chronic cervical MSC.

According to the models described by Moseley (56) and Loeser and Melzack (44), “*the cortical pain neuromatrix*” (Section 2.1.2, p. 7), both the peripheral nociceptive system and the non-nociceptive cognitive-evaluative mechanisms create and undergo profound changes in the presence of chronic pain, potentially leading to further changes in pain and motor control output. In the current study, the presence of clenching for the total sample was associated with both cervical disability (Section 4.9.1, p. 101) and the presence of anxiety/depression (Section 4.9.3, p. 101). Therefore, teeth clenching may be an indicator of psychosocial factors, and not purely of cervical dysfunction. These findings suggest the presence of a complex pathophysiological relationship between perceived levels of cervical disability and teeth clenching.

Subsequent secondary analysis with results for psychosocial factors of anxiety/depression as a grouping variable have shed some light on the integrative action of the CNS and its role in chronic cervical MSC (Table 4-9, p. 102).

5.6 Health related quality of life as a grouping variable

5.6.1 *Anxiety/depression and cervical disability*

Present study results showed that significantly worse scores on the NDI arose in participants reporting anxiety/depression. These findings are similar to descriptive study results that have conveyed the presence of anxiety/depression as a factor contributing to chronic cervical MSC (15,163). For instance, investigators have shown that significantly greater impairments in HRQoL and higher states of anxiety were found in those with chronic cervical disorders compared to controls (15,163). Similarly, after adjusting for confounders of age, gender, socio-economic status and other chronic pain or medical conditions, Smuts (2) observed that chronic spinal MSC within a South African context was significantly co-morbid with both anxiety and major depressive disorders. Further to her findings, it was shown the association between MSC and general mental disorders was stronger in females compared to males. Furthermore, psychological factors have been found to be one of the more potent predictors of the persistence and future course of chronic pain and long-term disability in general (47,60) and in disorders of cervical MSC (47,160,161,165).

However, the debate persists as to whether depression is a predictor of MSC (3,46,59,157,163), rather than a response to the experience of pain (2) due to anxiety and fear-avoidance (70). The cross-sectional design of the present study cannot make inferences on psychological factors and their cause or effect mechanisms to chronic cervical MSC.

5.6.2 *Anxiety/depression and pain*

There were significant differences in pain severity between those who did and did not report anxiety/depression. Analogous explanations on the contributory and predictive role of anxiety/depression on MSC-related pain may be provided as were given above in Section 5.6.1 (p. 127).

5.6.3 Anxiety/depression and clenching

In addition to significant differences in cervical disability and pain occurring in those with and without anxiety/depression, there were significant differences in the prevalence of teeth clenching relative to the presence of anxiety/depression. Once again, though the present study design cannot infer causal mechanisms, it appears more likely that the presence of anxiety/depression may influence daytime teeth clenching, and not vice versa. One could theorise that the presence of anxiety may act as a predictor to the presence of clenching. Nevertheless, it is of clinical relevance that significant biopsychosocial factors (including teeth clenching and anxiety/depression) are evident in those with chronic cervical MSC when compared to the no pain group.

5.6.4 Anxiety/depression and resting sEMG

No significant differences in masseter or CE sEMG activity at rest were observed between groups with and without anxiety/depression. In contrast, increases in resting muscle activity related to emotional load and mental load have been observed (110,125). Further, previous studies have revealed the presence of sEMG and autonomic changes in a clinical setting in the presence of psychophysiological stressors. These effects have been observed in both MSC-specific groups (low back pain, tension headache, TMD groups (56,85,86,131,139), as well as in healthy individuals (86). However, it was an objective of the present study to minimise performance bias, by encouraging standardised relaxation and training processes before the recording procedure.

Therefore, any potential measurement bias on the results was minimised.

Furthermore, the low levels of anxiety/depression reported for the total sample may have reduced possible differences recorded in masseter or CE sEMG activity at rest between those participants with and without anxiety/depression. Though the EQ-5D is considered a psychometrically robust and user friendly instrument for measuring HRQoL, the ordinal scales do not lend themselves to a high sensitivity for the recording of anxiety/depression levels within each category.

Following the overall results (p. 88), it appears that cervical disability in those with chronic cervical MSC is most significantly associated with the psychophysiological activity of teeth clenching and the biopsychosocial HRQoL factor of anxiety/depression. These variables seem far more significant in chronic cervical MSC, when compared to potential factors of motor adaptations and changes in resting sEMG activity in the cervico-mandibular muscles. This is confirmed by literature reporting that psychological factors, rather than biomedical or biomechanical risk factors, are the more potent predictors of the persistence and future course of chronic pain and long-term disability (47,60).

Therefore, the significance of these results lies in the inferred interaction between the three main factors of cervical disability, the parafunctional habit of teeth clenching, and anxiety/depression. In the presence of chronic pain, both the peripheral nociceptive system and the non-nociceptive cognitive-evaluative mechanisms create and undergo profound changes (56). Further, it is possible that similar forces drive teeth clenching to those that drive cervical disability (15,23,25,159,159,190). The presence of teeth clenching may form part of the altered motor control output observed due to changes seen in the CNS (in terms of anxiety/depression) in the presence of chronic pain (15,23,25,159,159,190). In order to gain an understanding of which mechanism dominates, a longitudinal study would need to be conducted. Similarly, cervical pain-related disability, according to the biopsychosocial model, may be regarded as an emotion intricately linked with the CNS, and not purely as a biomedical symptom (52,54,56,255).

5.7 Clinical relevance

The head and cervical area have been identified as areas of frequent chronic complaints within rural and peri-urban communities of SA (48-50,256). However, the high prevalence of complaints may be associated with a lack of clarity regarding the pathophysiological mechanisms of chronic pain generally, and chronic cervical pain specifically (50). It is theorised that the pathophysiological processes of chronic pain remain the key to understanding the aetiology of chronic pain syndromes, such as in chronic cervical MSC (10). The precise mechanisms behind chronic cervical MSC in office workers using information technology remain unclear (3).

Investigations driven by the dentistry profession for purposes of TMD management have focussed on the involvement of the cervical spine. Yet there is a paucity of literature on the potential influences of TMD on the cervical spine, thereby reducing identification of further potential contributory factors to chronic cervical MSC.

The results of the present study have highlighted the integrative action of the CNS and its role in chronic cervical MSC, namely the significant inter-related biopsychosocial factors of cervical disability, pain, parafunctional daytime teeth clenching habits, and HRQoL. There were no differences in sEMG in those with and without cervical pain. In the current study set in the presence of chronic cervical MSC, the lack of cervico-mandibular sEMG findings in relation to the other potent biopsychosocial factors including teeth clenching and anxiety/depression has further highlighted the complex pathophysiological mechanisms found in chronic pain, not limited purely to biomechanical influences.

This section offers the opportunity to highlight important clinical applications of the present study findings. The complex interactions between the cervical spine, the temporomandibular area, and biopsychosocial factors such as anxiety and depression suggest the presence of central sensitisation and CNS changes and drivers that occur in the presence of chronic pain and pain-related disability. It was earlier recognised (Section 2.1.2, p. 7) that in the presence of chronic pain, both the peripheral nociceptive and the central non-nociceptive systems generate and undergo profound changes. This is theorised to lead to long-term alterations in the CNS, and further changes in pain and motor control output, “*the cortical pain neuromatrix*” (44,54). In addition, the brain is able to generate or augment pain in the absence of nociceptive input from the periphery or spinal cord. Therefore, by influencing the inputs on the neuromatrix, one may be able to positively influence the output of the neuromatrix in patient populations. Consequently, the assessment and management of chronic cervical MSC may be made more effective by addressing cervical disability, teeth clenching habits and anxiety/depression as drivers that underlie chronic cervical MSC. Clinicians should adopt a truly biopsychosocial approach to ensure effective management of chronic cervical MSC.

5.8 Study limitations

A checklist for the present cross-sectional study is presented, according to the principles of Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (APPENDIX IX, p. 214). The STROBE checklist was completed to identify potential study limitations and areas for improvement in future research studies.

ITEM	CROSS-SECTIONAL STUDY CHECKLIST
1	<p><u>Title and abstract</u></p> <ul style="list-style-type: none"> - The title and abstract mention the cross-sectional design and descriptive nature of the correlations between sEMG and chronic cervical MSC. - Predictive mechanisms may not be discussed. This would require a longitudinal study.
2	<p><u>Introduction – background</u></p> <ul style="list-style-type: none"> - An exploration of the pathophysiological mechanisms of chronic cervical MSC using the theoretical framework of the biopsychosocial nature of chronic pain is presented.
3	<p><u>Introduction – objectives</u></p> <ul style="list-style-type: none"> - The objectives of the study were to measure sEMG activity of the masseter and CE muscles in individuals with pain from chronic cervical MSC and in control participants without pain, using: <ul style="list-style-type: none"> a) the sitting position at rest; b) posterior tooth contact (light teeth clench). - Further objectives were to explore relationships in those with pain and those without pain between chronic cervical MSC and: <ul style="list-style-type: none"> a) disability; b) occupational activities; b) leisure-related sporting activities; c) teeth clenching habits; d) health related quality of life (HRQoL); e) sEMG.

ITEM	CROSS-SECTIONAL STUDY CHECKLIST
4	<p><u>Methods - study design</u></p> <ul style="list-style-type: none"> - A cross-sectional single-blind descriptive study was conducted.
5	<p><u>Methods – setting</u></p> <ul style="list-style-type: none"> - Participants were recruited from the students and staff of UCT. - Bulletin and email advertisements were used for the recruitment process. - Data collection was limited to one visit per participant, via suitable appointment. - The venue for appointments was Old Main Building, Groote Schuur Hospital, in Cape Town.
6	<p><u>Methods – participants</u></p> <ul style="list-style-type: none"> - Convenience sampling of 20 chronic cervical pain and 22 no pain participants. - Females aged 21 to 45, with good comprehension of oral and written English. - Telephonic screening process for inclusion. - Pain group participants: “<i>mild disability</i>” category according to the NDI, reporting cervical pain for at least three to six months in the past year, or having experienced at least four recurrent episodes of cervical pain in the past year lasting three days or more. No pain group participants: no cervical disability, and free of pain (for which they required treatment). - Exclusion criteria of TMD for both groups.
7	<p><u>Methods - variables of interest</u></p> <ul style="list-style-type: none"> - Socio-demographic comparisons between groups. - Biopsychosocial comparisons between groups. - Physiological cervico-mandibular sEMG comparisons between groups. - Relationships between factors of cervical disability, pain and sEMG. - Secondary analysis of biopsychosocial factors of teeth clenching and anxiety/depression using these as grouping variables respectively.

ITEM	CROSS-SECTIONAL STUDY CHECKLIST
8	<p><u>Methods – measurement</u></p> <ul style="list-style-type: none"> - Bilateral masseter and CE sEMG recording at rest and during light clench, with normalisation of data using respective muscle's MVC. - Completion of five validated questionnaires.
9	<p><u>Methods – bias</u></p> <ul style="list-style-type: none"> - Participants in both groups were matched in regard to gender, occupation and age, in order to limit sample bias. - The PI remained blinded to the screening process to eliminate bias prior to sEMG data collection and comparison.
10	<p><u>Methods – sample size</u></p> <ul style="list-style-type: none"> - Sample size calculated on reported differences in sEMG levels of the CE in individuals with and without cervical pain, using a significance level of $p < 0.05$ and a power of 0.9.
11	<p><u>Methods – statistical methods</u></p> <ul style="list-style-type: none"> - Man-Whitney U and X^2 tests were used for non-parametric comparisons of numerical and categorical data between the pain and no pain groups. - Spearman correlation tests were used for detection of associations in the numerical and categorical data of biopsychosocial factors and resting cervico-mandibular sEMG data.
12	<p><u>Methods – quantitative exposures</u></p> <ul style="list-style-type: none"> - The study was a descriptive correlational qualitative study. - The study did use sEMG methodology as a quantitative measure, using standardised methodology of electrode application and normalisation of data.
13	<p><u>Methods – funding</u></p> <ul style="list-style-type: none"> - Funding was awarded by the Research Foundation of the South African Society of Physiotherapy.

ITEM	CROSS-SECTIONAL STUDY CHECKLIST
14	<p><u>Results – participants</u></p> <ul style="list-style-type: none"> - 49 participants were potentially eligible (reasons for exclusion were: Two participants were not UCT employees; three participants were outside the age range of 21 to 45 years; one participant had had the removal of more than one tooth per quadrant excluding third molars; and one participant was receiving current cervical treatment). - 42 participants were screened telephonically. - 42 participants were included in the study. - 42 participants were analysed.
15	<p><u>Results – descriptive data</u></p> <ul style="list-style-type: none"> - Pain and no pain groups were matched in terms of gender, age, BMI, occupation, hand dominance, occupational and sporting activities, and ethnic group. - Data was collected via five validated questionnaires.
16	<p><u>Results – outcome data</u></p> <ul style="list-style-type: none"> - One summary measure for seven individual socio-demographic characteristics that were not significant between groups. - Six summary measures for biopsychosocial factors that were significant between groups. - Two summary measures for cervico-mandibular sEMG activity that were not significant between groups (at rest and during light clench). - Two summary measures for relationships between factors of cervical disability and pain and sEMG. - Differences in NDI, pain, HRQoL, and sEMG using teeth clenching as grouping variable. - Differences in NDI, pain, teeth clenching, and sEMG using anxiety/depression as grouping variable.

ITEM	CROSS-SECTIONAL STUDY CHECKLIST
17	<p data-bbox="236 293 528 327"><u>Results – main results</u></p> <ul style="list-style-type: none"> <li data-bbox="236 360 1485 495">- Group differences for biopsychosocial factors of disability ($p < 0.01$), pain from BPI ($p < 0.01$), presence of teeth clenching ($p = 0.01$), state of health VAS ($p = 0.02$), pain/discomfort index from EQ-5D ($p < 0.01$), anxiety/depression ($p = 0.05$). <li data-bbox="236 528 1485 663">- No group differences in cervico-mandibular EMG activity at rest and during light clench at $p > 0.05$. Further, no group differences in cervico-mandibular sEMG rate of change (firing pattern) during teeth clench at $p > 0.05$. <li data-bbox="236 696 1485 786">- Associations existed between cervical disability and pain severity for the total sample ($Rho = 0.80$; $p < 0.05$), pain group ($Rho = 0.72$; $p < 0.05$), and no pain group ($Rho = 0.50$; $p < 0.05$). <li data-bbox="236 819 1485 954">- Associations between cervical disability, pain and occupational activities: A weak positive correlation existed with disability only for the control group ($Rho = 0.39$; $p < 0.05$). A weak positive correlation existed with pain only for the control group ($Rho = 0.43$; $p < 0.05$). <li data-bbox="236 987 1485 1077">- Associations between cervical disability, pain and leisure-related activities: A weak negative correlation existed with disability (not pain) only for the no pain group ($Rho = -0.35$; $p < 0.05$).
18	<p data-bbox="236 1111 560 1144"><u>Results – other analyses</u></p> <ul style="list-style-type: none"> <li data-bbox="236 1178 448 1211">- Not applicable.

ITEM	CROSS-SECTIONAL STUDY CHECKLIST
19	<p><u>Discussion – key findings</u></p> <ul style="list-style-type: none"> - Both physiological and psychosocial variables were found to influence chronic cervical MSC, revealing better understanding of pathophysiological mechanisms in chronic cervical pain-related disability. - The factors of cervical disability, presence of teeth clenching, and anxiety/depression appear to be integrated.
20	<p><u>Discussion – limitations</u></p> <ul style="list-style-type: none"> - Average to low level of cervical disability reported in the pain group may have potentially dampened results in biopsychosocial relationships. - Methodological limitations of previous studies for comparative purposes with present study (due to varying definitions and inclusion of heterogeneous samples). - The use of larger time measures (greater than 10 seconds) for the recording of sEMG may have revealed additional findings.
21	<p><u>Discussion – generalisability</u></p> <ul style="list-style-type: none"> - Results cannot be generalised as a true representation of male or female office workers within the general community.
22	<p><u>Discussion – interpretation</u></p> <ul style="list-style-type: none"> - The present cross-sectional study observed the intergrated influences of cervical disability, teeth clenching and anxiety/depression as CNS drivers behind chronic cervical MSC, but did not attempt to state which mechanisms dominate. - A longitudinal study may assist in determining which of the mechanisms of cervical disability, teeth clenching and anxiety/depression dominates.

Strengths and weaknesses to the study are presented according to the STROBE checklist. In particular, limitations to the study may exist in the average to low level of cervical disability reported in the pain group. Consequently, potential dampening of the biopsychosocial relationships and differences in sEMG may have occurred. Further methodological limitations to the present study exist in the narrow socio-demographic profile of the total sample for comparative purposes between groups.

The superficial erector spinae and their proximity to the trapezius may have resulted in sEMG cross talk (130) thereby influencing sEMG recordings of the study. Further, skin folds may have resulted in motion of the electrodes (130). Lastly, the use of short duration time measures of 10 seconds for the recording of sEMG may have potentially reduced any findings between pain and no pain groups (85,86,131). Studies have confirmed, through sEMG and electroencephalography, the presence of psychophysiological responses to internal and external stimuli that increase with chronicity. The procedures for obtaining sEMG resting levels have generally included adaptation phases of 12 minutes, followed by two minute recordings (86).

It is recommended that sampling over a broad socio-economic and socio-demographic population be used to explore the biopsychosocial factors in chronic cervical MSC. In addition, larger time measures of approximately two minutes are to be used for the recording of sEMG.

CHAPTER 6: CONCLUSION

The present study sought to determine cervico-mandibular muscle activity in females with chronic cervical pain. There is evidence to suggest that the pathophysiological mechanisms that underlie the pain may be linked to biopsychosocial factors extending from the cervical spine to encompass the temporomandibular area.

The novel findings of the present study were identification of significant biopsychosocial differences and relationships associated with chronic cervical MSC, with regards to teeth clenching habits and anxiety/depression. A purely biomechanical representation of cervical pain-related disability was not found to be the case. These findings appear to both agree (2,15,47,160,161,163) and conflict (65,109,112,115-120) with previous research. Furthermore, exploration of the cervico-mandibular muscles in those with chronic cervical MSC, at the exclusion of those with TMD, has hopefully assisted in expanding the literature on chronic cervical MSC in female office workers (110,116,123-125). However, a number of important differences between previous studies and the present one may provide an explanation for the outcomes.

In the present study, the methodological limitations identified in previous studies on cervical disorders were addressed. These improvements included employment of strict exclusion criteria for co-morbid TMD syndromes, and the standardisation and normalisation processes for interpretation of cervico-mandibular sEMG data. With these applications in mind, the present study objectives of measuring sEMG activity in the masseter and CE muscles in individuals with chronic cervical MSC and in no pain control participants were implemented in the sitting position at rest and during posterior tooth contact (light teeth clench). As a result, conclusions were drawn between chronic cervical MSC and biopsychosocial factors of occupational and leisure-related sporting activities, sEMG, teeth clenching habits, and HRQoL.

The overall aim of this thesis was to explore the activity levels of the cervico-mandibular muscles in females with chronic cervical musculoskeletal conditions, who showed no symptoms of TMD. Based on the evidence provided in this thesis, the study objectives, as described in Section 1.3 on p. 2 may be answered as follows:

i. Chronic cervical MSC, occupational activities, and leisure-related sporting activities

There was no significant association observed between cervical disability and the socio-demographic variables of frequency of sitting hours and frequency of sports-related activities. These findings may add to the debate on cervical posture and prolonged sitting as factors that contribute to chronic cervical MSC.

ii. Chronic cervical MSC and sEMG

Surface EMG of the CE and masseter muscles was no different between those with and without cervical disability. Further, sEMG was no different between those who did and did not clench, and those with and without anxiety/depression.

iii. Chronic cervical MSC and teeth clenching habits, with teeth clenching as a grouping variable

Significant differences in cervical disability level, pain/discomfort, and anxiety/depression were demonstrated in those who clench. It appears that similar psychosocial factors of anxiety/depression (as a subgroup of HRQoL) that drive teeth clenching may drive chronic cervical pain.

iv. Chronic cervical MSC and HRQoL, with anxiety/depression as a grouping variable

Significant differences in cervical disability level, pain, perceived state of health, and teeth clenching were demonstrated in those with anxiety/depression.

Further, the interactive relationships observed between cervical disability, the presence of teeth clenching, and anxiety/depression may have alluded to the presence of central sensitisation and CNS changes and drivers that occur in the presence of chronic pain and pain-related disability. The combined affective/cognitive inputs of teeth clenching and anxiety/depression on the cortical neuromatrix seem to determine further output of disability, parafunctional teeth clenching habits and anxiety/depression (more than motor adaptations).

Therefore, the clinician's role in successfully managing the chronic pain cycle of chronic cervical MSC may lie in addressing the biopsychosocial factors of cervical disability itself, the presence of a teeth clenching habit, and levels of anxiety/depression. The clinician may be able to alter or reduce the inputs on the neuromatrix, thereby positively affecting the output of the neuromatrix (44,54,56). Therefore, a truly biopsychosocial approach using validated and reliable measurement tools may ensure effective assessment and management of chronic cervical MSC patients within the clinical setting.

CHAPTER 7: REFERENCES

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University of Cape Town

APPENDIX I

FORMAL ETHICS APPROVAL

UNIVERSITY OF CAPE TOWN



Health Sciences Faculty
Faculty of Health Sciences Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • Facsimile [021] 406 6411
e-mail: sumayah.ariefdien@uct.ac.za

01 September 2010

HREC REF: 316/2010

Ms T Lang
c/o Dr T Burgess
Health & Rehab

Dear Ms Lang

PROJECT TITLE: CERVICO-MANDIBULAR MUSCLE ACTIVITY IN FEMALES WITH CHRONIC CERVICAL PAIN: A DESCRIPTIVE, CROSS-SECTIONAL, CORRELATIONAL STUDY

Thank you for submitting your study to the Health Science Faculty Research Ethics Committee for review

It is a pleasure to inform you that the Ethics Committee has **formally approved** the above-mentioned study.

Approval is granted for one year till the 15th September 2011.

Please submit a progress form, using the standardised Annual Report Form (FHS016), if the study continues beyond the approval period. Please submit a Standard Closure form (FHS010) if the study is completed within the approval period.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the REC. REF in all your correspondence.

Yours sincerely



PROFESSOR M BLOCKMAN
CHAIRPERSON, HSF HUMAN ETHICS

Federal Wide Assurance Number: FWA00001637.
sAriefdien

APPENDIX II

LETTERS OF APPROVAL FOR STUDENT AND STAFF ACCESS

	RESEARCH ACCESS TO STUDENTS	DSA 100
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NOTES

- This form must be completed by applicants that want to access students for the purpose of research. Attach your research proposal.
- Return Completed application forms to: Moonira.Khan@uct.ac.za; or deliver to: Attention: Executive Director, Department of Student Affairs, North Lane, Steve Biko Students' Union, Room 7.22, Upper Campus, UCT.
- The turnaround time for a reply is approximately 10 working days.
- NB: It the responsibility of the researcher/s to apply for ethical clearance to the relevant (a) Faculty's 'Research in Ethics Committee' (RiEC), and (b) to the Executive Director, HR to access staff for research purposes.
- For noting, a requirement of UCT is that items (1) and (4) apply even if prior clearance has been obtained by the researcher/s from any other institution.

SECTION A: PERSONAL DETAILS

Position	Staff / Student Reference No	Title and Name	Contact Details
Student Number	BSRPAT001	Ms Patricia Lang	0828466186
Academic / PASS Staff No.			
Visiting Researcher – ID No.			
Contact details of faculty officer for inquiries	School of Health and Rehab Sciences	Secretary: Naomi	021-4066628
University / institution at which employed / or a registered student	UCT	Address if not UCT:	
Faculty and Department	Health and Rehab Sciences, Physiotherapy		
Division / School / Unit	Physiotherapy		
APPLICANTS DETAILS	Title and Name	Tel.	Email
	Ms P lang	0828466186	trish.lang@mweb.co.za

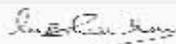
SECTION B: SUPERVISOR DETAILS

Position	Title and Name	Tel.	Email
Supervisor	Mrs Romy Parker	021-4066571	romy.parker@uct.ac.za
Co-Supervisor	Ms Theresa Burgess	021-4066171	theresa.burgess@uct.ac.za
Co-Supervisor			

SECTION C: APPLICANTS STUDY FIELD AND TITLE OF RESEARCH PROJECT / STUDY

Degree	Masters by Dissertation in Physiotherapy
Research Project / Title	Cervico-mandibular muscle activity in females with chronic cervical pain: a descriptive cross-sectional study.
Research Proposal attached	Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>
Target population	Staff, students, faculty @ UCT
Lead Researcher details	P Lang MSc student BSRPAT001
Research Methodology and Informed consent	Cross-sectional design, volunteer recruitment through convenience sampling, informed consent
Ethical clearance status	HREC REF 316/2010

SECTION D: APPROVAL STATUS - FOR ACCESS TO STUDENTS FOR RESEARCH PURPOSE (To be completed by the ED, DSA or Nominee)

APPROVAL GRANTED	Ref. No.: BSRPAT001	Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>	Comments	
APPROVED BY	Title and Name	Designation	Signature	Date
	Ms Moonira Khan	Executive Director Department of Student Affairs		28 October 2010

From: Margie Tainton [Margie.Tainton@uct.ac.za]
Sent: Wednesday, October 27, 2010 2:22 PM
To: Joy Henry
Cc: trish.lang@mweb.co.za
Subject: Fwd: RE: Trish Lang-Ethical approval,Proposal, Advertisement

Dear Joy and Trish

The impact in terms of staff is minimal so I will approve it for the staff. Please go ahead and the bulletins will be fine.

kind regard

Margie Tainton

HR Manager: Remuneration & Administration

Human Resource Department

University of Cape Town

Tel: 021 650 3028 Fax: 021 650 4778 Email: Margie.Tainton@uct.ac.za

>>> Joy Henry 2010/10/27 01:03 PM >>>

trish.lang@mweb.co.za

UNIVERSITY OF CAPE TOWN

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APPENDIX III

ADVERTISEMENT

STUDENTS, STAFF, FACULTY FROM HEALTH SCIENCES:

FEMALE PARTICIPATION IN PHYSIOTHERAPY STUDY REQUESTED

This study has been approved by the Faculty of Health Sciences Human Research Ethics Committee, University of Cape Town (HREC REF: 316/2010).

Would you like to take part in a physiotherapy study exploring neck pain in females?

You are a candidate for the study if you fit into ANY one of these two categories:

- We are looking for females at UCT (students, staff, faculty) with a good comprehension of English aged between 21 and 45 years of age who **have** experienced moderate neck pain for at least three to six months in the past year, or have experienced at least four recurrent episodes of neck pain in the past year lasting three days or more

OR

- We are looking for females at UCT (students, staff, faculty) with a good comprehension of English aged between 21 and 45 years of age who do **not** experience neck pain

Participation required is for ONE day only, for approximately one hour.

Participation is voluntary.

There is no financial compensation.

The venue will be in the Old Main Building, Groote Schuur Hospital in Cape Town.

What is the study about? Your participation is greatly appreciated, in order to further the research done on CHRONIC NECK PAIN. Surface Electromyographic measurement of the resting muscle activity of the neck and the jaw will be analysed in participants with and without neck pain.

Please make use of the contact details provided, at the specified times. Quote the term “*UCT Neck Research*” when you phone, and we will return your call. A brief interview will be conducted on the phone, in order to confirm inclusion criteria for the study and to book you for an allocated date and time in the near future. Please invite your colleagues to contact Carin as well!

Thanking you

Contact person CARIN	082 466 9699
MON	8.00 am - 8.00 pm
WED	8.00 am - 8.00 pm
THURS	2.00 pm – 8.00 pm
FRI	8.00 am – 2.00 pm

University of Cape Town

APPENDIX IV

TELEPHONIC SCREENING BY THE ASSESSOR

This study has been approved by the Faculty of Health Sciences Human Research Ethics Committee, UCT. Participation required is for ONE day only, for approximately one hour. Participation is voluntary. There is no financial compensation. The venue will be in the Old Main Building, Groote Schuur Hospital in Cape Town. Parking is available in P3 level. The parking fee will be reimbursed to you on presentation of your ticket to us, at the end of your visit.

Your participation is greatly appreciated, in order to further the research done on chronic neck pain. Surface electromyographic measurement of the resting electrical muscle activity of the neck and the jaw will be analysed in individuals with and without neck pain.

The following questions will allow us to select the appropriate participants for this study. Please simply answer YES or NO to the following questions:

- Do you have a good written and oral comprehension of English? IF YES, CONTINUE
- Are you between the ages of 21 to 45 years? IF YES, CONTINUE
- Have you had a history of neck trauma, fractures, or whiplash? IF NO, CONTINUE
- Have you had a history of jaw trauma, fractures, or surgical history? Removal of wisdoms does not count. IF NO, CONTINUE
- Are you currently receiving neck or jaw treatment (does not imply over the counter pain medication)? IF NO, CONTINUE
- Have you experienced any facial pain at present or in the last three months (in the form of pain in and around the ear, eye, nose, temples)? IF NO, CONTINUE
- Your mouth is divided into 4 sections: top and bottom, left and right. If you exclude removal of wisdoms, has more than one tooth been removed per section anywhere in your mouth? IF NO, CONTINUE

- Are you suffering from any diagnosed medical systemic problems, such as myalgia, myositis or fibromyalgia? IF NO, CONTINUE
- Throughout our lives, most of us have had pain from time to time (such as minor knee pain, headaches, sprains, and toothaches). Do you suffer from pain anywhere in your body other than these everyday kinds of pain, during the last week? = FROM QUESTION 3 BPI- Appendix VI. IF NO, CONTINUE.

IF YES, ASK THEM TO RATE THEIR AVERAGE PAIN/10 OF THAT PROBLEM (“IF 10 IS AS BAD AS YOU CAN IMAGINE AND 1 IS NO PAIN”).

IF LESS THAN 5, CONTINUE.

Thank you for your patience; just a few more questions. These questions will allow us to recruit suitable participants for the study, and should assist us in preventing your making an unnecessary visit to us. Please do not feel offended if your specific criteria do not match ours.

- In the past six months, on average, how intense was your facial pain rated on a 0 to 10 scale where 0 is “no pain” and 10 is “pain as bad as could be”? (That is, your usual pain at times you were experiencing pain) = PAIN INTENSITY POINTS, FROM QUESTION 9 RDC/TMD- Appendix VI
- About how many days in the last six months have you been kept from your usual activities (work, school or housework) because of facial pain? = DISABILITY POINTS WHERE < 31 DAYS = 0 to 2 POINTS; > 31 DAYS, FROM QUESTION 10 RDC/TMD
- In the past six months, how much has facial pain interfered with your daily activities rated on a 0 to 10 scale where 0 is “no interference” and 10 is “unable to carry on any activities”? = MEAN DISABILITY SCORE, FROM QUESTION 11 RDC/TMD

Neck pain is defined as pain anywhere from the base of the skull downwards to the lower part of the shoulder blade, extending sideways toward the tip of the shoulder at the back.

Option 1:

- Have you experienced neck pain for at least six months or have experienced at least four recurrent episodes of neck pain in the past year lasting three days or more? IF NO, GO TO OPTION 2. IF YES, CONTINUE

Or Option 2:

- Are you someone who experiences no neck pain? IF YES, CONTINUE

These standardized questions apply whether you suffer from neck pain or not:

- Please choose 1 answer: I have no neck pain; My neck pain is mild; My neck pain comes and goes and is moderate; My neck pain is moderate and does not vary much; My neck pain is severe but comes and goes; My neck pain is severe and does not vary much = 0 to 5 LEVEL OF DISABILITY POINTS, FROM QUESTION 1 NDI - Appendix VI
- Please choose 1 answer: I can lift heavy weights without extra neck pain; I can lift heavy weights but it causes extra neck pain; Neck pain prevents me from lifting heavy weights off the floor, but I can if they are positioned suitably like on a table; I can only lift very light weights due to neck pain = 0 to 5 LEVEL OF DISABILITY POINTS, FROM QUESTION 3 NDI - Appendix VI
- Please choose 1 answer: I have no trouble sleeping; My sleep is slightly disturbed by neck pain by less than 1 hour; My sleep is mildly disturbed by neck pain by 1 to 2 hours; My sleep is moderately disturbed by 2 to 3 hours; My sleep is greatly disturbed by 3 to 5 hours = 0 to 5 LEVEL OF DISABILITY POINTS, FROM QUESTION 9 NDI - Appendix VI

Give the venue, date and time. Say that further explanation of the study will be provided and queries will be answered on the date provided. Consent forms will be signed. They are assured that it is a one day commitment only, of approximately 1 hour. THANK YOU

APPENDIX V

INFORMATION SHEET AND CONSENT FORM

Consent form

A study investigating female computer-users with and without long-term neck pain:
Measurement of electrical activity of the neck and jaw muscles, and determination of factors that play a role.

Dear participant

Ms Trish Lang will be conducting a Physiotherapy Masters study comparing individuals with and without long-term neck pain. The study will use surface electromyography to assess and record neck and jaw muscle activity that is present during the relaxed seated position. This study has been given Ethical Approval by the Faculty of Health Sciences Human Research Ethics Committee, University of Cape Town. The reference number is HREC REF: 316/2010.

A relationship exists between the neck and jaw area that allows for the one area to influence the other. However more research is required to look at this association in individuals who already have neck pain. It is hoped that the results of this study shall add to the body of knowledge of neck pain, which we know has a major effect on sickness absence and long-term disability.

This study will be supervised by Romy Parker and Theresa Burgess of the Division of Physiotherapy. Please read this form carefully and thoroughly before signing.

The appointed process for today:

Thank you for your participation. You are here today because you fall within one of two categories: You are between the ages of 21 and 45 and have experienced moderate neck pain for at least three to six months in the past year, or have experienced at least four recurrent episodes of neck pain in the past year lasting three days or more

Or

You are between the ages of 21 and 45 and do not experience neck pain.

We are currently executing the familiarisation session and signing of the informed consent forms. Once you have completed the consent form you will be allocated a participant number which will be used only for you. You are ensured anonymity, as this participant number will be the reference used for the results of this study. All personal details will be kept confidential.

Please fill in your assigned number at the top of each questionnaire. You will also be asked to provide a contact telephone number on the first questionnaire. This is to allow the investigator to contact you should she require any clarification about your answers in the questionnaire. Your telephone number will not be given to anyone else and will not be used for any other purpose.

The entire assessment and testing procedure will occur over the subsequent one hour approximately. A total of five questionnaires will be filled in, and should not take more than 15 to 20 minutes for you to complete. Please answer ALL of the questions in ALL of the questionnaires. They are:

The Research Diagnostic Criteria History questionnaire (RDC/TMD): The questions posed determine whether or not you experience jaw pain or facial discomfort. The questionnaire also asks about other symptoms such as jaw noises, and whether you have daytime teeth clenching habits or not. The results will allow us to confirm whether or not your profile fits the criteria for this study.

The Neck Disability Questionnaire (NDI): The questions are based on whether you experience long-term neck pain or not, and how this pain may influence various daily activities. It is based on a point system, which will be used for research purposes.

The Computer Usage Questionnaire (CUQ): The questions are based on your routine computer usage at the office and at home. A section on leisure-related activity and sport is included.

The Brief Pain Inventory (BPI): On a body diagram, you will be requested to shade in any areas in which you may have pain, whether it is in your neck or anywhere else. However, it is very important to note that these areas of pain in the drawing must not be the normal minor day to day pain that is experienced throughout our lives (such as headaches, knee pain, sprains, toothache). If true pain is experienced, the subsequent questions will ask you to rate the pain out of 10.

The EuroQol quality of life measure (EQ-5D): This last questionnaire asks your opinion on your own health state – whether good or bad, based on multiple choice answers and a diagram.

Once all participants have completed the questionnaires, you will be requested to hand them directly to the assessor. They will be reviewed to confirm inclusion into the study. Those who do not fit the criteria for the study will be provided next door with a refreshment and relevant parking fee reimbursement. Those who do fit the criteria for the study will be prepped with an alcohol swab for the placement of disposable electrodes to the face and neck. According to numerical sequence, each participant will be guided to the investigator for the surface electromyographic testing, and will be clearly instructed in the seated position. Four sets of similar instructions will be clearly given, with a 30 to 60 second rest between each set. No stress or strain will be applied to the neck or jaw muscles.

Potential risks:

There are no dangers associated with surface electromyography, as it is a non-invasive tool for gathering information on muscle properties. There will be minimal exposure to the harmless radio signals for a very limited time. The electrodes are single use, participant-specific and are disposed once testing is complete. The alcohol swab is gentle on skin. The skilled physiotherapist investigator will perform the testing procedure according to evidence-based clinical practice.

Benefits to participants:

Participants will be helping research on neck pain and its contributory factors. An information pamphlet on general physiotherapy advice will be provided upon completion. Beverage refreshments and a parking fee reimbursement on presentation of your ticket will also be offered. You will be referred to physiotherapy services if requested, or if indicated by the findings of this study. No financial compensation is available for participation in this study.

Questions or concerns:

If there are any questions or concerns regarding the study, please feel free to use the contact numbers provided on the following page. All enquiries will be kept confidential.

Trish Lang

Tel: 021-4236206

Fax: 086 5910645

Physical Address: Trish Lang Physios

Room 301, Christiaan Barnard Annexe

162 Longmarket Street

Cape Town

8001

Email: trish.lang@mweb.co.za

Romy Parker

Tel: 021-4066431

Fax: 021 406 6323

Physical Address: Division of Physiotherapy

School of Health and Rehabilitation

University of Cape Town,

Groote Schuur Hospital

Anzio Road

Observatory

7725

E-mail: romy.parker@uct.ac.za

Theresa Burgess

Tel: 021-4066171

Fax: 021 406 6323

Physical Address: Division of Physiotherapy

School of Health and Rehabilitation

University of Cape Town

Groote Schuur Hospital

Anzio Road

Observatory

7725

E-mail: theresa.burgess@uct.ac.za

Professor Marc Blockman

Tel: 021- 406 6492

Chairperson

Faculty of Health Sciences

Human Research Ethics Committee, UCT

E-mail: marc.blockman@uct.ac.za

Please note that UCT does offer a no-fault insurance that will cover all participants in the event that something may go wrong. You must notify the study investigators immediately of any injuries during the trial, whether they are research-related or other related complications. UCT reserves the right not to provide compensation if, and to the extent that, your injury came about because you chose not to follow the instructions that you were given while taking part in the study. Your right in law to claim compensation for injury where you prove negligence is not affected.

Please place your signature below once you have read and clearly understood the consent form. Your signature will confirm that you are willing to participate in this study, and that you have had an opportunity to ask questions, and that any concerns have been addressed. You have the right to withdraw from the study at any time. All the information recorded will be held confidential.

Signature of volunteer Name (Please print) Date

Signature of witness Name (Please print) Date

Signature of investigator Name (Please print) Date

Left or right handed? (Please circle one)

Weight (kg) _____ Height _____

Participant number: _____

APPENDIX VI

MEASUREMENT INSTRUMENTS

ADAPTED RDC/TMD HISTORY QUESTIONNAIRE

(Dworkin & LeResche, 1992)

Participant Number _____

Tel _____ Date

____/____/____

Please read each question and respond accordingly. For each of the questions below circle only one response.

1. Would you say your health in general is excellent, very good, good, fair or poor?

Excellent..... 1
Very good2
Good.....3
Fair4
Poor.....5

2. Would you say your oral health in general is excellent, very good, good, fair or poor?

Excellent..... 1
Very good2
Good.....3
Fair4
Poor.....5

3. Have you had pain in the face, jaw, temple, in front of the ear or in the ear in the past month?

No.....0
Yes1

[If no pain in the past month SKIP to question 14]

If Yes,

4.a. How many years ago did your facial pain begin for the first time? _____
years ago

[If one year ago or more SKIP to question 5]

[If less than one year ago, code 00]

4.b. How many months ago did your facial pain begin for the first time? ___ ___ months ago

5. Is your facial pain persistent, recurrent
or was it only a one-time problem?

Persistent.....	1
Recurrent.....	2
One-Time.....	3

6. Have you ever gone to a physician, dentist,
chiropractor or other health professional
for facial ache or pain?

No	1
Yes, in the last six months.....	2
Yes, more than six months ago.....	3

7. How would you rate your facial pain on a 0 to 10 scale at the present time, that is right now, where 0 is "no pain" and 10 is "pain as bad as could be"?

..... PAIN AS BAD

NO PAIN AS
COULD BE

0 1 2 3 4 5 6 7 8 9 10

8. In the past six months, how intense was your worst pain rated on a 0 to 10 scale where 0 is "no pain" and 10 is "pain as bad as could be"?

..... PAIN AS BAD

NO PAIN AS
COULD BE

0 1 2 3 4 5 6 7 8 9 10

9. In the past six months, on the average, how intense was your pain rated on a 0 to 10 scale where 0 is "no pain" and 10 is "pain as bad as could be"? [That is, your usual pain at times you were experiencing pain].

..... PAIN AS BAD

NO PAIN AS
COULD BE

0 1 2 3 4 5 6 7 8 9 10

10. About how many days in the last six months have you been kept from your usual activities (work, school or housework) because of facial pain?

_____ DAYS

11. In the past six months, how much has facial pain interfered with your daily activities rated on a 0 to 10 scale where 0 is "no interference" and 10 is "unable to carry on any activities"?

NO INTERFERENCE

UNABLE TO CARRY ON ANY ACTIVITIES

0 1 2 3 4 5 6 7 8 9 10

12. In the past six months, how much has facial pain changed your ability to take part in recreational, social and family activities where 0 is "no change" and 10 is "extreme change"?

NO INTERFERENCE

UNABLE TO CARRY ON ANY ACTIVITIES

0 1 2 3 4 5 6 7 8 9 10

1. In the past six months, how much has facial pain changed your ability to work (including housework) where 0 is "no change" and 10 is "extreme change"?

NO INTERFERENCE

UNABLE TO CARRY ON ANY ACTIVITIES

0 1 2 3 4 5 6 7 8 9 10

14.a. Have you ever had your jaw lock or catch so that it won't open all the way? No 0
Yes 1

[If no problem opening all the way
SKIP to question 15]

If Yes,

14.b. Was this limitation in jaw opening severe enough to interfere with your ability to eat? No0
Yes1

15. a. Does your jaw click or pop when you open or close your mouth or when chewing? No0
Yes1

b. Does your jaw make a grating or grinding noise when it opens and closes or when chewing? No0
Yes1

c. Have you been told, or do you notice that you grind your teeth or clench your jaw while sleeping at night? No0
Yes1

- d. During the day, do you grind your teeth or clench your jaw? No 0
Yes 1
- e. Does your jaw ache or feel stiff when you wake up in the morning? No 0
Yes 1
- f. Do you have noises or ringing in your ears? No 0
Yes 1
- g. Does your bite feel uncomfortable or unusual? No 0
Yes 1
- 16.a. Do you have rheumatoid arthritis, lupus, or other systemic arthritic disease? No 0
Yes 1
- 16.b. Do you know of anyone in your family who has had any of these diseases? No 0
Yes 1
- 16.c. Have you had or do you have any swollen or painful joint(s) other than the joints close to your ears (TMJ)? No 0
Yes 1

[If no swollen or painful joints, SKIP to question 17.a.]

If Yes,

16.d. Is this a persistent pain which you have had for at least one year? No0
Yes1

17.a. Have you had a recent injury to your face or jaw? No0
Yes1

[If no recent injuries SKIP to question 18] If Yes,

17.b. Did you have jaw pain before the injury? No0
Yes1

18. During the last six months have you had a problem with headaches or migraines? No0
Yes1

19. What activities does your present jaw problem prevent or limit you from doing?

a. Chewing No0
Yes1

b. Drinking No0
Yes1

c. Exercising No0
Yes1

20. In the last month, how much have you been distressed by. . .

		Not <u>At All</u>	A Little <u>Bit</u>	Moder- <u>ately</u>	Quite <u>A Bit</u>	Ex- <u>tremely</u>
a.	Headaches	0	1	2	3	4
b.	Loss of sexual interest or pleasure	0	1	2	3	4
c.	Faintness or dizziness	0	1	2	3	4
d.	Pains in the heart or chest	0	1	2	3	4
e.	Feeling low in energy or slowed down	0	1	2	3	4
f.	Thoughts of death or dying	0	1	2	3	4
g.	Poor appetite	0	1	2	3	4
h.	Crying easily	0	1	2	3	4
i.	Blaming yourself for things	0	1	2	3	4
j.	Pains in the lower back	0	1	2	3	4
k.	Feeling lonely	0	1	2	3	4
l.	Feeling blue	0	1	2	3	4
m.	Worrying too much about things	0	1	2	3	4

n.	Feeling no interest in things	0	1	2	3	4
o.	Nausea or upset stomach	0	1	2	3	4
p.	Soreness of your muscles	0	1	2	3	4
q.	Trouble falling asleep	0	1	2	3	4
r.	Trouble getting your breath	0	1	2	3	4
s.	Hot or cold spells	0	1	2	3	4
t.	Numbness or tingling in parts of your body	0	1	2	3	4
u.	A lump in your throat	0	1	2	3	4

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In the last month, how much have you been distressed by. . .

		Not <u>At All</u>	A Little <u>Bit</u>	Moder- <u>ately</u>	Quite <u>A Bit</u>	Ex- <u>tremely</u>
v.	Feeling hopeless about the future	0	1	2	3	4
w.	Feeling weak in parts of your body	0	1	2	3	4
x.	Heavy feelings in your arms or legs	0	1	2	3	4
y.	Thoughts of ending your life	0	1	2	3	4
z.	Overeating	0	1	2	3	4
aa.	Awakening in the early morning	0	1	2	3	4
bb.	Sleep that is restless or disturbed	0	1	2	3	4
cc.	Feeling everything is an effort	0	1	2	3	4
dd.	Feelings of worthlessness	0	1	2	3	4
ee.	Feeling of being caught or trapped	0	1	2	3	4
ff.	Feelings of guilt	0	1	2	3	4

21. How good a job do you feel you are doing in taking care of your health overall?

- Excellent..... 1
- Very good2
- Good.....3
- Fair4
- Poor.....5

22. How good a job do you feel you are doing in taking care of your oral health?

- Excellent..... 1
- Very good2
- Good.....3
- Fair4
- Poor.....5

23. When were you born?

Month ___ Day ___ Year ___

24. Which of the following group best represents your race?

- White 1
- Black.....2
- Indian.....3
- Coloured4
- Other5

25. Which from the following group best represents your PRESENT status?

Married 1

Widowed.....2

Divorced3

Separated.....4

Never married.....5

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AXIS II SCORING CRITERIA FOR RDC/TMD

Scoring criteria for grading chronic pain severity

Characteristic pain intensity is a 0 to 100 score derived from Questions 7 through 9:

Mean [Pain right now, Worst pain, Average pain] X 10

Disability score is 0 to 100 score derived from Questions 11 through 13:

Disability points: Add the indicated points for Disability days (Question 10) and for Disability score.

Disability points

<u>Disability days (0 - 180)</u>		<u>Disability score (0 - 100)</u>	
0 - 6 Days	0 Points	0 - 29	0 Points
7 - 14 Days	1 Point	30 - 49	1 Point
15 - 30 Days	2 Points	50 - 69	2 Points
31+ Days	3 Points	70+	3 Points

Classification

Grade 0 No TMD pain in prior 6 months

Low disability

Grade I (Low intensity) Characteristic pain intensity < 50, and less than 3 Disability points

Grade II (High intensity) Characteristic pain intensity \geq 50 and less than 3 Disability points

High disability

Grade III (Moderately limiting) 3 to 4 Disability points, regardless of characteristic pain intensity

Grade IV (Severely limiting) 5 to 6 Disability points, regardless of characteristic pain intensity

NECK DISABILITY INDEX

(Vernon & Mior, 1991)

Participant number _____

INSTRUCTIONS: Please read:

This questionnaire is designed to enable us to understand how much your neck pain has affected your ability to manage everyday activities. Please answer each Section by circling the ONE CHOICE that most applies to you. We realize that you may feel that more than one statement may relate to you, but please just circle the one choice which closely describes your problem right now.

NECK DISABILITY INDEX	
SECTION 1: Pain Intensity A. I have no pain at the moment. (0 pts) B. The pain is mild at the moment. (1 pt) C. The pain comes & goes & is moderate. (2 pts) D. The pain is moderate & does not vary much. (3 pts) E. The pain is severe but comes & goes. (4 pts) F. The pain is severe & does not vary much. (5 pts)	SECTION 6: Concentration A. I can concentrate fully when I want to with no difficulty. (0 pts) B. I can concentrate fully when I want to with slight difficulty. (1 pts) C. I have a fair degree of difficulty in concentrating when I want to. (2 pts) D. I have a lot of difficulty in concentrating when I want to. (3 pts) E. I have a great deal of difficulty in concentrating when I want to. (4 pts) F. I cannot concentrate at all. (5 pts)
SECTION 2: Personal Care (Washing, Dressing etc.) A. I can look after myself without causing extra pain. (0 pts) B. I can look after myself normally but it causes extra pain. (1 pts) C. It is painful to look after myself and I am slow & careful. (2 pts) D. I need some help but manage most of my personal care. (3 pts) E. I need help every day in most aspects of self-care. (4 pts) F. I do not get dressed; I wash with difficulty and stay in bed. (5 pts)	SECTION 7: Work A. I can do as much work as I want to. (0 pts) B. I can only do my usual work but no more. (1 pt) C. I can don most of my usual work but no more. (2 pts) D. I cannot do my usual work. (3 pts) E. I can hardly do any work at all. (4 pts) F. I cannot do any work at all. (5 pts)

SECTION 3: Lifting

- A. I can lift heavy weights without extra pain. (0 pts)
- B. I can lift heavy weights, but it causes extra pain. (1 pt)
- C. Pain prevents me from lifting heavy weights off the floor, but I can if they are conveniently positioned, for example on a table. (2 pts)
- D. Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned. (3 pts)
- E. I can only lift very light weights. (4 pts)
- F. I cannot lift or carry anything at all. (5 pts)

SECTION 8: Driving

- A. I can drive my car without neck pain. (0 pts)
- B. I can drive my car as long as I want with slight pain in my neck. (1 pt)
- C. I can drive my car as long as I want with moderate pain in my neck. (2pts)
- D. I cannot drive my car as long as I want because of moderate pain in my neck. (3 pts)
- E. I can hardly drive my car at all because of severe pain in my neck. (4pts)
- F. I cannot drive my car at all. (5 pts)

SECTION 4: Reading

- A. I can read as much as I want to with no pain in my neck. (0 pts)
- B. I can read as much as I want with slight pain in my neck. (1 pts)
- C. I can read as much as I want with moderate pain in my neck. (2 pts)
- D. I cannot read as much as I want because of moderate pain in my neck. (3pts)
- E. I cannot read as much as I want because of severe pain in my neck. (4pts)
- F. I can not read at all because of neck pain. (5 pts)

SECTION 9: Sleeping

- A. I have no trouble sleeping. (0 pts)
- B. My sleep is slightly disturbed (less than 1 hour sleepless). (1 pt)
- C. My sleep is mildly disturbed (1-2 hours sleepless). (2 pts)
- D. My sleep is moderately disturbed (2-3 hours sleepless). (3 pts)
- E. My sleep is greatly disturbed (3-5 hours sleepless). (4 pts)
- F. My sleep is completely disturbed (5-7 hours sleepless). (5 pts)

SECTION 5: Headache

- A. I have no headaches at all. (0 pts)
- B. I have slight headaches that come infrequently. (1 pt)
- C. I have moderate headaches that come infrequently. (2 pts)
- D. I have moderate headaches that come frequently. (3 pts)
- E. I have severe headaches that come frequently. (4 pts)
- F. I have headaches almost all the time. (5 pts)

SECTION 10: Recreation

- A. I am able to engage in all recreational activities with no pain in my neck at all. (0 pts)
- B. I am able to engage in all recreational activities with some pain in my neck. (1 pts)
- C. I am able to engage in most, but not all, recreational activities because of pain in my neck. (2 pts)
- D. I am able to engage in only a few of my usual recreational activities because of pain in my neck. (3 pts)
- E. I can hardly do any recreational activities because of pain in my neck. (4pts)
- F. I cannot do any recreational activities at all. (5 pts)

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SCORING:

Simply count up the points and plug the total in below: For each question there is a possible of 5 points: 0 for the first question, 1 for the second question, 2 for the third question etc.

CATEGORIES:

Raw score	Level of disability:
0 - 4	No disability
5 - 14	Mild disability
15 - 24	Moderate disability
25 - 34	Severe disability
35 - 50	Completely disabled

University

COMPUTER USAGE QUESTIONNAIRE

(Smith et al, 2008)

Participant Number _____

COMPUTER USE AT THE OFFICE.....

If you don't use a computer at the office, go to "COMPUTER USE ELSEWHERE" on the next page.

Please mark your answer with a cross (X).

1. How long have you been using a computer at the office?

Less than 1 year 2 years 3 years 4 years or more

2. How many times per week do you use the computer at the office?

Once or less per week Twice per week Three times per week Four times per week Five times or more per week

3. During one session at the office, how long do you spend using the computer?

Less than 30 minutes About 45 minutes 1 Hour 1 ½ Hours 2 Hours or more

4. How many hours per day do you spend working on the office computer?

About 2 Hours per day About 4 Hours per day About 6 Hours per day 8 Hours or more per day

5. Do you take a short break of a few minutes at least once an hour, when using the computer? (A short computer break, means to stop using your hands at the keyboard/ mouse, e.g. to stand up, stretch out, use the bathroom, etc.)

Yes No

COMPUTER USE ELSEWHERE....

If you don't use a computer outside of the office, go to "YOUR SPORTS" section below.

Please mark your answer with a cross (X).

1. Where do you use a computer outside of the office? Mark as many as you want.

At your home Internet Café Relative/ friend's home Library

Elsewhere (state where) _____

2. Roughly, how long have you been using the computer outside of the office?

Less than a year 2-3 Years 4 Years 5 years or more

3. On average, how many times per week do you use the computer outside of the office?

Less than once a week 2 times per week 3 times per week 4 times per week

Five times or more per week

4. On average, how many hours per day do you spend working on the computer outside of the office?

Less than 30 minutes 1 Hour 2 Hours 3 Hours 4 Hours or more

5. What type of computer do you use most of the time, whether at the office or elsewhere?

Desktop computer Laptop computer Both

6. Where is the computer positioned when you are using it? Mark as many as you want.

On a desk/ table On your lap On the floor On a chair

Other, please list _____

7. Do you participate in any other activity whilst simultaneously working on the computer outside of the office? Mark as many as you want.

Talk to a friend Listen to music Talk on the phone Writing on a page

Other, please list _____

YOUR SPORTS

Please mark your answer with a cross (X).

1. Do you participate in sports?

Yes No..... If "No", go to the end. Thank you.

2. If "Yes", which sports do you participate in? Mark as many as you want.

Rugby Soccer Tennis Cricket Netball

Athletics Hockey Other, please list _____

3. How many times per week do you participate in your combined sporting activities?

Less than once a week Once a week Twice a week Three times or more per week

4. On average, how many hours per day do you participate in all your sports?

Less than an hour About 2 Hours About 4 Hours 6 Hours or more

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE

BRIEF PAIN INVENTORY

(Cleeland & Ryan, 1994)

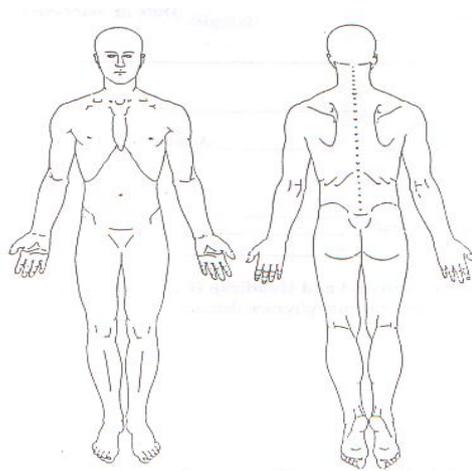
Participant Number: _____

Date: _____

1. Throughout our lives, most of us have had pain from time to time (such as minor headaches, sprains, and toothaches). Have you had pain other than these everyday kinds of pain during the last week?

Yes No

2. On the diagram, shade in the areas where you feel pain. Put an X on the area that hurts the most.



3. Please rate your pain by circling the one number that best describes your pain at its **worst** in the last week.

0 1 2 3 4 5 6 7 8 9 10

No

Pain as bad as

Pain

you can imagine

4. Please rate your pain by circling the one number that best describes your pain at its **least** in the last week.

0 1 2 3 4 5 6 7 8 9 10

No

Pain as bad as

Pain

you can imagine

5. Please rate your pain by circling the one number that best describes your pain on the **average**.

0	1	2	3	4	5	6	7	8	9	10
No										Pain as bad as
Pain										you can imagine

6. Please rate your pain by circling the one number that tells how much pain you have **right now**.

0	1	2	3	4	5	6	7	8	9	10
No										Pain as bad as
Pain										you can imagine

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EUROQOL-5D

(Jelsma et al, 2004)

Participant number _____

EQ - 5D

Health Questionnaire

South African English version

By placing a tick in one box in each group below, please indicate which statements best describe your own state of health TODAY.

Mobility

- I have no problems in walking about
- I have some problems in walking about
- I am confined to bed

Self-Care

- I have no problems with self-care
- I have some problems washing or dressing myself
- I am unable to wash or dress myself

Usual Activities (e.g. work, study, housework, family or leisure activities)

- I have no problems with performing my usual activities
- I have some problems with performing my usual activities
- I am unable to perform my usual activities

Pain/Discomfort

- I have no pain or discomfort
- I have moderate pain or discomfort
- I have extreme pain or discomfort

Anxiety/Depression

- I am not anxious or depressed
- I am moderately anxious or depressed

I am extremely anxious or depressed

Compared with my general level of health over the past 12 months, my state of health today is:

Better

PLEASE TICK

Much the same

ONE

Worse

BOX

University of Cape Town

To help people say how good or bad their state of health is, we have drawn a scale on which the best state you can imagine is marked 100 and the worst state you can imagine is marked 0.

We would like you to indicate on this scale, in your opinion, how good or bad your own health is today. Please do this by drawing a line from the box below to whichever point on the scale indicates how good or bad your state of health is today.

**Your own
state of health**

Best
imaginable

100

90

80

70

60

50

40

30

20

10

0

Worst

APPENDIX VII

TECHNICAL SPECIFICATIONS

MyoTrace 400 specifications

Noraxon U.S.A., Inc

13430 North Scottsdale Road, Ste. 104

Scottsdale, Arizona 85254

Toll free: (800) 364-8985

Phone: (480) 443-3413

Fax: (480) 443-4327

Email: info@noraxon.com

Website: www.noraxon.com

Physical dimensions

- Length: 6.6875 in (16.98 cm)
- Width: 4.375 in (11.11 cm)
- Height: 1.1875 in (2.73 cm)
- Weight: 13.5 oz (382.7 g)

Electrical specifications

- Operating voltage: 2.6 V to 4.2 V
- Analog input voltage range: -5.0 V to +5.0 V
- Battery charger voltage: 5 V DC
- Battery: 4.2 V Li-ion rechargeable battery

Hardware filters

- All channels have low pass anti-alias filters set to 500 Hz

PC Interface specifications

Physical dimensions

- Length: 2.5 in (6.35 cm)
- Width: 2 in (5.08 cm)
- Height: 0.81 in (2.06 cm)
- Weight: 1.6 oz (45.4 g)

Electrical specifications

- Operating voltage: 5V
- Power source: 5 V USB Bus Power

EMG active lead specifications

- Baseline noise < uV RMS
- Input impedance > 100 MOhms
- CMR > 100 dB
- Input range ± 3.5 mV
- Base gain 500
- Highpass filter at 10 Hz $\pm 10\%$

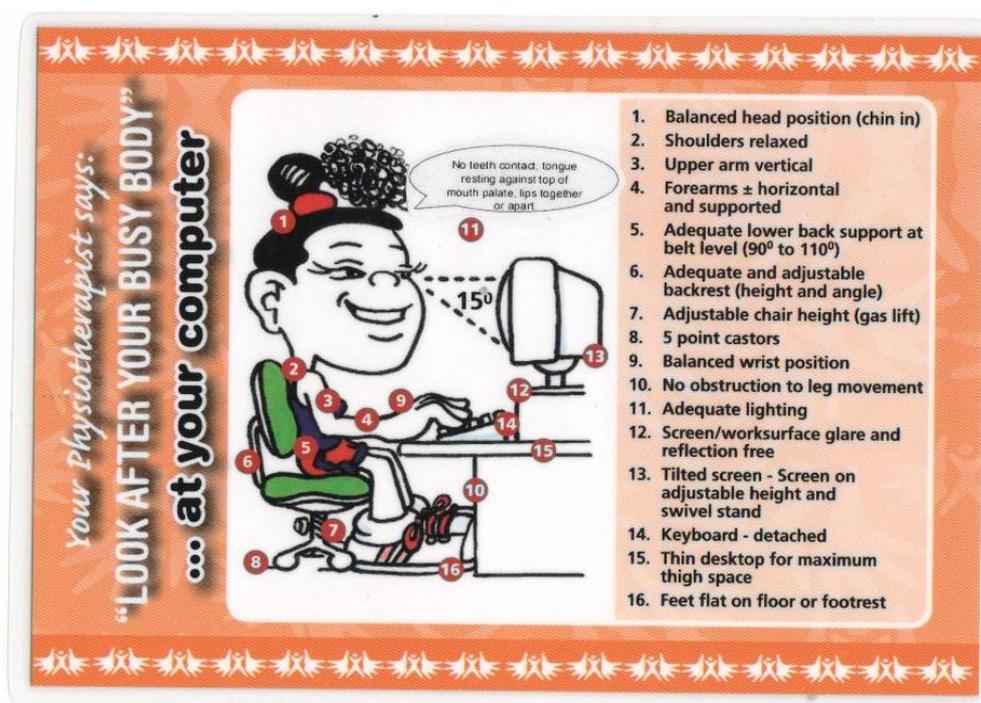
EMG electrode specifications

- Blue sensor electrodes manufactured by Ambu www.noraxon.com
- Type N-00-S paediatric electrodes, diameter 0.8 cm
- Ag/AgCl electrodes with decentralised snaps
- Disposable, self-adhesive

APPENDIX VIII

PHYSIOTHERAPY INFORMATION PAMPHLET

A “thank you information pamphlet” was handed to each participant following sEMG data collection. Refer to the scanned pamphlet below, as well as additional information regarding the pamphlet.



Postural instructions were listed in points 1 to 16 and were easy to follow with the aid of the diagram. In addition, the diagram caption instruction read: “no teeth contact, tongue resting against top of mouth palate, lips together or apart”.

Permission was granted by the South African Society of Physiotherapy, according to the email below, for the use of “the friends of physio” logo for the purposes of this pamphlet. Refer to the email below

Dear Trish

You have permission to modify the flier, as per the received attachment.

Regards

Amanda Pandy

Head Office Administrator

South African Society of Physiotherapy

Unit 4, Parade on Kloof Office Park, Bedfordview

Tel: + 27 11 615 3170

Fax: 086 559 8237/ 086 679 0681



Please don't print this email unnecessarily

From: Trish Lang [mailto:trish.lang@mweb.co.za]

Sent: 22 October 2010 11:04 AM

To: admin@saphysio.co.za

Subject: Patricia Lang- SASP logo and modification

TRISH LANG PHYSIOS

Practice number 072000 0084026

Patricia Lang

Registered Physiotherapist

B.Sc (UCT)

Tel: +27 21 423 6206

Fax: 086 591 0645

Cell: +2782 8466 186

Room 301

162 Longmarket Street

Christiaan Barnard Annexe

(Formerly City Park Hospital)

Cape Town, 8001

Dear Amanda

Thanks for the chat

Please, hopefully if this is approved, could I request in writing a quick confirmation that I have been given the “authority” to “modify” this SASP public flier in this way (see attachment), and provide it for public free consumption.

Thanks

Trish

(LAN266)

University of Cape Town

APPENDIX IX

STROBE statement: Checklist of essential items Version 2 (April 2005)

	<i>Item #</i>	<i>Cohort</i>	<i>Case-control</i>	<i>Cross-sectional</i>
TITLE & ABSTRACT	1	(a) Identify the article as a cohort study in the title or the abstract. (b) The abstract should be a highly informative structured summary of the article, taking account of all issues in the checklist below.	(a) Identify the article as a case-control study in the title or the abstract.	(a) Identify the article as a cross-sectional study in the title or the abstract.
INTRODUCTION				
Background / Rationale	2	Explain scientific background and rationale for the study.		
Objectives	3	State specific objectives and hypotheses.		
METHODS				
Study design	4	Present key elements of study design. State purpose of original study, if article is one of several from an ongoing study.		
Setting	5	Describe setting, locations and dates defining periods of data collection.		
Participants	6	Give eligibility and exclusion criteria, source and methods of selection of participants. If applicable, describe exposed and unexposed separately. Give period of follow-up.	For cases and controls separately, give eligibility and exclusion criteria, source and methods of selection of cases and controls. Give precise diagnostic criteria for cases, and rationale for choice of controls. For matched studies, give matching criteria and number of controls per case.	Give eligibility and exclusion criteria, source and methods of selection of participants.

Variables of interest	7	List and clearly define all outcomes, potential predictors and confounders, and predefined subgroups.	List and clearly define all exposures, potential confounders, and predefined subgroups.	List and clearly define all outcomes, potential predictors and confounders, and predefined subgroups.
Measurement	8	(a) For each variable of interest give details of methods of assessment. (b) Describe comparability of procedures across groups, if applicable.	(b) Describe comparability of procedures in cases and controls.	(b) Describe comparability of procedures across groups, if applicable.
Bias	9	Describe any measures taken to address potential sources of bias.		
Sample size	10	Describe rationale for study size, including practical and statistical considerations.		
Statistical methods	11	(a) Describe all statistical methods, including those to control for confounding, and how loss to follow-up and missing data were addressed. (b) If applicable, describe methods for subgroup analyses and sensitivity analyses.	(a) Describe all statistical methods including those to control for confounding. Account for matching and missing data.	(a) Describe all statistical methods, including those to control for confounding and account for any design effects and missing data.
Quantitative exposures	12	(a) Give a clear explanation of how quantitative exposures are analyzed, e.g. which groupings are chosen, and why. (b) Present results from continuous analyses as well as from grouped analyses, if appropriate.		
Funding	13	Give source of funding and role of funder(s) for the present study and, if applicable, the original study on which the present report is based.		

RESULTS				
Participants	14	(a) For each group, report the number of potentially eligible individuals, the number examined for eligibility (if known), the number eligible, the number included in the study, the numbers completing follow up, and the number analysed. Report dates defining the follow-up.	(a) For cases and controls separately, report the number of potentially eligible individuals (if known), the number examined for eligibility, the number eligible, the number included in the study, and the number analysed. For matched studies, give distribution of number of controls per case.	(a) Report the number of potentially eligible individuals, the number examined for eligibility (if known), the number eligible, the number included in the study, and the number analysed.
		(b) Give reasons for non-participation at each stage of process. A flow diagram is recommended.		
Descriptive data	15	(a) Give baseline characteristics of study participants (e.g. demographic, clinical, social) and information on exposures and potential confounders, by comparison group if applicable. Summarize average and total amount of follow up.	(a) Give characteristics of cases and controls (e.g. demographic, clinical, social) and information on exposures and potential confounders.	(a) Give characteristics of study participants (e.g. demographic, clinical, social) and information on exposures and potential confounders, by comparison group if applicable.
		(b) Indicate for each variable of interest the completeness of the data.		
Outcome data	16	Report numbers of outcome events or summary measures over time, for each comparison group (e.g. exposure category) if applicable.	Report numbers of cases and controls for each exposure category.	Report numbers of outcome events or summary measures, for each comparison group (e.g. exposure category) if applicable.

Main results	17	(a) Give unadjusted and confounder adjusted measures of association and their precision (e.g. 95% confidence intervals). Make clear which confounders were adjusted for and on what grounds they were included and others were not. (b) If applicable translate relative measures into absolute risk differences.
Other analyses	18	Report any other analyses performed, e.g. subgroup analyses and sensitivity analyses.
DISCUSSION		
Key findings	19	Summarize key findings with reference to study hypotheses.
Limitations	20	Discuss limitations of the study, taking into account sources of potential bias or imprecision, and problems that could arise from multiplicity of analyses, exposures and outcomes.
Generalizability	21	Discuss the generalizability (external validity) of the study findings.
Interpretation	22	Give a cautious overall interpretation of the results in the context of current evidence and study limitations, paying attention to alternative interpretations.