University of Alberta

RELATIONSHIP BETWEEN CERVICAL MUSCULOSKELETAL IMPAIRMENTS AND TEMPOROMANDIBULAR DISORDERS: CLINICAL AND ELECTROMYOGRAPHIC VARIABLES

by

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Dedication

To all my family

To my parents Gladys, Manuel, my siblings Cynthia, Loreto and Victor, my nephews Alvaro, Benjamin and David and my beautiful niece Sofita, my brothers in law Samuel and Rodrigo, and mein Liebling Bernhardito.

Abstract

Temporomandibular disorders (TMD) consist of a group of pathologies affecting the masticatory muscles, the temporomandibular joint and related structures. The association between the cervical spine and TMD has been studied from different perspectives; however, the study of cervical muscles and their significance in the development and perpetuation of TMD has not been elucidated. Thus, this project was designed to investigate the association between cervical musculoskeletal impairments and TMD. A sample of subjects who attended the TMD/Orofacial Pain clinic, and students and staff at the University of Alberta participated in this study. All subjects underwent a series of physical tests and electromyographic assessment (i.e. head and neck posture, maximal cervical muscle strength, cervical flexor and extensor muscles endurance, and cervical flexor muscle performance) to determine cervical musculoskeletal impairments. All subjects were asked to complete the Neck Disability Index and the Jaw Function Scale, and the Chronic Pain Grade Disability Questionnaire. A strong relationship between neck disability and jaw disability was found (r=0.82). Craniocervical posture (measured using the eye-tragus-horizontal angle) was statistically different between patients with myogenous TMD and healthy subjects. However, the difference was too small (3.3º) to be considered clinically relevant. Maximal cervical flexor muscle strength was not statistically or clinically different between patients with TMD and healthy subjects. No statistically significant differences were found in electromyographic activity of the sternocleidomastoid or the anterior scalene muscles in patients with TMD when compared to healthy subjects while executing the craniocervical flexion test (p=0.07). However, clinically important effect sizes (0.42-0.82) were found. Subjects with TMD presented with reduced cervical flexor as well as extensor muscle endurance while performing the flexor and extensor muscle endurance tests when compared to healthy individuals. Furthermore, patients with mixed TMD presented with steeper (although modest) negative slopes at several times during the neck extensor muscle endurance test than healthy subjects. The results of this research provided an important clinical contribution to the area of physical therapy and TMD. It identified impairments in the cervical spine in patients with TMD that could help guide clinicians in the assessment and prescription of more effective interventions for individuals with TMD.

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Abbreviations

AA	Atlantoaxial
AO	Atlantooccipital
AS	Anterior Scalene
ASs	Anterior Scalenes
CCFT	Craniocervical Flexion Test
CEH	Cervicogenic Headache
CFP	Craniofacial Pain
CI	Confidence Intervals
CMD	Craniomandiular Disorders
CMMR	Common Mode Rejection Ratio
CMS	Craniomandibular System
CPGDC	Chronic Pain Grade Classification
CPGDCQ	Chronic Pain Grade Classification Questionnaire
CSA	Cross Sectional Area
CSD	Cervical Spine Dysfunction
CTs	Clinical Trials
EMG	Electromyography
ES	Effect size
FFT	Fast Fourier Transform
HADS	Hospital Anxiety and Depression Scale
ICC	Intraclass Correlation Coefficient
ICF	The International Classification of Functioning, Disability, and Health
JDC	Jaw Disability Checklist
JFS	Jaw Function Scale
KRC	Known Referential Contraction
KRSC	Known Referential Submaximal Contraction
LDF-TMDQ	Limitations of Daily Functions in TMD Questionnaire
MDF	Median Frequency
MFPS	Myofascial Pain Syndrome
MNF	Mean Spectral Frequency
MRI	Magnetic Resonance Imaging
MUAP	Motor Unit Action Potential
MUs	Motor Units
MVC	Maximal Voluntary Contraction
MVIC	Maximal Voluntary Isometric Contraction
MVRC	Maximal Voluntary Referential Contraction
NDI	Neck Disability Index
NEMET	Neck Extensor Muscle Endurance Test
NME	Neuromuscular Efficiency
NS	Nociceptive Specific
RCTs	Randomized controlled trials
RDC/TMD	Research Diagnostic Criteria for Temporomandibular

	Disorders
RMS	Root Mean Square
ROM	Range of Motion
SC	Subnucleus Caudalis
SCM	Sternocleidomastoid
SEM	Standard Error of the Measurements
SEPQ	Eysenck Personality Questionnaire Short Form
SMD	Standardized Mean Difference
SS	Stomatognathic System
SVC	Submaximal Voluntary Contraction
TMD	Temporomandibular Disorders
TMJ	Tempormandibular Joint
TP	Trigger Point
TPs	Trigger Points
VAS	Visual Analogue Scale
WAD	Wiplash Asociated Disorders
WDR	Dynamic Range Neurons
WHO	World Health Organization

1 CHAPTER 1

INTRODUCTION, OBJECTIVES AND GENERAL LITERATURE REVIEW

1.1 INTRODUCTION

Temporomandibular disorders (TMD) consist of a group of pathologies affecting the masticatory muscles, the temporomandibular joint, and related structures.[1, 2] TMD constitute a major public health problem as they are one of the main sources of chronic orofacial pain interfering with daily activities. TMD are also commonly associated with other symptoms affecting the head and neck region such as headache, ear related symptoms, cervical spine dysfunction, [3, 4] and altered head and cervical posture. [5-15] It has been reported that pain in the cervical musculoskeletal tissues may be referred to cranial structures including the jaw muscles,[16, 17] and thus, a connection between cervical muscle dysfunction and jaw symptoms could exist.[18-21] Additionally, experimental animal studies have revealed considerable convergence of craniofacial and cervical afferents in the trigeminocervical nucleus and upper cervical nociceptive neurons.[22-27] Nociception resulting from cervical dysfunction increases central sensitization in the trigeminocervical nucleus and thus, diffusing the pain in the cranial zone. [28] All of this evidence has been implicated as a basis for pain localization and referral along with neuromuscular adaptations in these two regions.[29-32]

The neuroanatomic relationship between the cervical spine and orofacial pain is provided by the interconnection between the trigeminal nerve and the first cervical nerve roots. Studies in animals have supported this connection. [26, 27, 33-36] At the level of the trigeminocervical nucleus, there is an overlapping pattern of ramification of primary afferent fibers coming from various peripheral nerves. For example, pain from the occipital area, the dura mater, and the vertebrobasilar arterial tree may travel in the first, second and third cervical nerves, and terminating at the common second –order neurons in this nucleus.[37] All three upper cervical spine nerves intermingle at multiple segments and converge with the trigeminal afferents on cells in the dorsal grey column of the C1-C3 segments. Due to this convergence, pain from any of the upper three pair of cervical synovial joints (apophyseal) and muscles innervated by upper spinal cervical nerves could be referred to regions innervated by the trigeminal nerve and pain from any orofacial structure innervated by the trigeminal nerve could be referred to cervical regions innervated by the upper cervical nerves. [38-45] The convergence between the cervical spinal and orofacial structures in the subnucleus caudalis was demonstrated by Sessle et al.[27] in cats. They reported that input from different types of afferents (i.e. the skin of the mucosal areas of the mouth, tooth pulp, tongue muscles, larynx, temporomandibular joint and neck) converge in the caudalis nucleus of the trigeminal nerve. Also, these authors demonstrated that stimulation of high-threshold afferents from the jaw and tongue muscles as well as the neck muscles excited wide dynamic–range (WDR) neurons, low-threshold mechanoreceptive, and nociceptive specific (NS) neurons in the caudalis nucleus.[27] These neuroplastic changes involving the trigeminal nerve and the cervical afferents convergence within the subnucleus caudalis demonstrate the connection between the craniofacial and facial tissues. [46, 47] In addition, some current experiments, also in animals, have studied the involvement of the trigeminal brainstem sensory nuclear complex in pain in the craniofacial region and its relationship with cervical structures. Yu et al. [36] studied the effects of the application of inflammatory irritant mustard oil into rat's temporomandibular joints (TMJ) on jaw and neck muscles activity. The irritation of the TMJ caused an increase in the activity of the masticatory muscles as well as the activity of cervical muscles. In addition, another experiment on cats [33] demonstrated that bradykinin injected into the temporomandibular joint, through stimulation of nerve endings in the TMJ, changed the sensitivity of muscle spindles in dorsal muscles. [33] The authors of this study concluded that the reflex connections between the TMJ nociceptors and the fusimotor-muscle spindle system of the dorsal neck muscles might be involved in the pathophysiological mechanisms responsible for the sensory-motor disturbances in the neck region found in patients with TMD. Other authors also found that stimulation of cervical paraspinal tissues by an inflammatory irritant (mustard oil) resulted in an inflammatory response in the paraspinal tissues and increased EMG activity in the masticatory muscles as well as the cervical muscles.[24] In addition, application of glutamate to masseter muscle and splenius cervicis muscle in rats evoked responses in WDR and NS neurons in the first cervical dorsal horn.[48] Some recent evidence has proposed that subnucleus caudalis (SC) and C1 and C2 dorsal horns may act together as one functional unit to process nociceptive information from craniofacial and cervical tissues. [48, 49] Therefore, from analyzing the evidence, one could say that pain coming from orofacial region or cervical spine could be interpreted as coming from either region (i.e. orofacial or cervical spine) since sensory information coming from both areas is integrated at the trigeminocervical nucleus, and thus responses to this pain could be directed to either place (i.e. orofacial or cervical spine).

It has been seen that pain from painful muscles will cause a change in the activity of these muscles as well as the activity of the synergist and antagonist muscles. This has been described by Lund et al., as the “Pain Adaptation Model”.[50] These changes at the central level can change the motor behavior of the painful muscles and thus lead to muscular dysfunction. For example, the application of painful chemical substance such as hypertonic saline, capsaicin, glutamate, or mustard oil to the TMJ, jaw muscles or other craniofacial tissues can activate neurons in the subnucleus caudalis (SC). The connection of these neurons from the SC to the brainstem reflex centers, such as the V motor nucleus, can result in alteration in the muscular activity of the jaw muscles and also an alteration in the activity of the cervical muscles.[36] It has been shown that the fusimotor muscle spindle system of dorsal neck muscles is altered during and after stimulation of bradykinin-sensitive nerves endings in neck muscles, masseter and cervical joints. These findings demonstrate that there are potent reflex connections between the nociceptors in the TMJ, jaw muscles, and the motoneurons of neck muscles. Thus, central sensitization could affect both orofacial and cervical systems. This has been recently proven in rats. Deep cervical nociceptive inputs produced central sensitization (i.e. receptive field expansion) of many nociceptive neurons from the subnucleus caudalis and C1/C2 dorsal horns.[51] Yu et al.,[36] suggested that activation of TMJ nociceptive afferents and changes in central neural plasticity induced by inputs from the TMJ nociceptive afferents may be related to clinically based concepts of muscular dysfunction in the masticatory muscles as well as the cervical muscles. Therefore, these findings in animals highlight the close relationship between sensory and motor pathways and indicate that excitatory reflex pathways exist from the peripheral craniofacial nociceptors to motoneurons in the V motor nucleus. [52] Thus, if one knows that pain originating and being maintained either in orofacial region or cervical region is integrated at the level of trigeminal cervical nucleus (due to convergence) and send it to superior centers where it is modulated through descending mechanisms, one could infer that central sensitization of the caudalis nucleus could affect the motor response of the orofacial muscles as well as the cervical muscles.[33] If trigeminocervical nucleus is sensitized, it could trigger changes in motor activity in the masticatory as well as the cervical muscles. These changes could lead to the development of masticatory and cervical muscular dysfunction.[53, 54] (p. 13-14, 208)

It has been shown that an alteration of the cervical muscle performance, strength and endurance occurs in the presence of neck pain.[55-63] Falla et al. [55, 60, 64] found that patients with neck pain tended to increase the activity of their superficial muscles (i.e. sternocleidomastoid and scalene muscles) instead of increasing the activity of their deep muscles (i.e. longus colli and longus capitis) when compared with control subjects. This pattern of contraction could be seen as an adaptative response to pain. This co-contraction generates increased loads in the spine [65-67], thus making the spine susceptible to overloading and causing potential damage to the tissues. In addition, an altered motor recruitment strategy (i.e. muscular dysfunction) involving mainly a reduction in deep muscle action and increased activity of superficial muscles in the cervical spine decreases the fine regulation of spinal control in presence of pain.[63] This strategy is probably used by the body to protect the spine in the short term, but it appears to be associated with reduction in fine motor control, particularly between segments, and places spinal structures at risk of nociceptive stimulation and injury in the long term [68]. Also, differences in mean spectral frequency (MNF) [a electromyographic (EMG) measurement to express muscle fatigue] and the normalized MNF slope have been shown in presence of pain, demonstrating that patients have greater fatigability of the superficial muscles at moderate and low loads (i.e. 25 and 50% of the maximal voluntary contraction (MVC)) than normal subjects [60]. Some clinical studies have also found reduced endurance of the flexor cervical muscles in conditions such as neck pain, [69-75] whiplash associated disorders (WAD)[76] and cervicogenic headache [77-79] In addition, reduced maximal strength has also been observed in these neck-related disorders (i.e. neck pain,[55, 64] whiplash associated disorders (WAD)[61, 62] and cervicogenic headache [80, 81]). Muscle endurance and strength as well as proper muscle recruitment patterns are key elements for proper cervical muscle function.

Theoretically, when the cervical muscles lose endurance or strength, their performance is impaired and the balance between the extensor and flexor cervical muscles will be interrupted and as a result, improper posture and alignment could lead to cervical dysfunction.[71] Therefore, muscular functioning is important to maintain the stability of the cervical system and to enhance the spinal support to pain-sensitive spine structures.

Some clinical evidence of interconnection between the cervical spine and temporomandibular disorders has been demonstrated and thus Cervical Spine Dysfunction (CSD) has been associated with TMD.[18-21] De Wijer et al.[18, 21, 82, 83] concluded that symptoms of the stomatognathic system overlap in patients with TMD and CSD, and symptoms from the cervical spine overlap in the same group of patients (TMD and CSD). It has also been found that patients with chronic TMD more often suffered from cervical spine pain than those without this disorder [19] and asymptomatic functional disorders of the cervical spine occurred more frequently in patients with internal derangement of the TMJ than in a control group.[84] Sippila et al. [85] found that facial pain was associated with reported neck pain and clinical pain resulting from palpation in the muscles of the neck-occiput area. Ciancagliani et al.[86] demonstrated that patients suffering from TMD had more than double the risk (odds ratio of 2.33) of suffering neck pain than patients without TMD (odds ratio of 1). Based on these results, they suggested that an association between neck pain and TMD may be possible and a systematic clinical examination of cervical spine areas could be important in identifying possible causes of craniofacial pain and guide possible treatments.

The interconnection between cervical spine and TMD, as presented above, has been supported by neurophysiological and clinical research. Patients with TMD have been shown to have cervical spine dysfunction concomitantly with TMD. However, the quality of the evidence investigating this association needed to be scrutinized in order to determine how strong the evidence connecting cervical spine involvement and TMD was and to determine the areas where knowledge enhance was needed concerning assessment and treatment for people with TMD. In addition, the evaluation of this cervical dysfunction in patients with TMD has only been subjectively evaluated through a general clinical examination of the cervical spine (signs and symptoms). According to Nederhand et al.,[87, 88] the clinical evaluation to detect cervical dysfunction is questionable because manually tested musculoskeletal signs have shown a poor interexaminer reliability and very little is known about their diagnostic validity.[89] Thus, it is necessary that more objectives ways to examine the CSD in patients with TMD are performed. In this way, more concrete information regarding cervical musculoskeletal impairments in subjects with TMD could be obtained and therefore more effective treatment options could be implemented. Since physical therapists work mainly on the muscular system through the use of exercises and since the evidence of a recent systematic review [90] favored the use of exercises addressing the neck to improve function and decrease jaw pain in subjects with TMD, it was clear that research focusing more specifically on the cervical spine, and its musculoskeletal impairments and their association with TMD could clarify the role of the cervical muscles in the symptomatology of patients with TMD.

Summarizing, the anatomic-neurological [22, 26, 27] and biomechanical relationship between the cervical spine and the stomatognathic system (SS) [91-94] is a foundation that associates the normal functions of the craniomandibular system (CMS) and its pathological aspects.[43, 95-99] Due to the neurological interconnection between the cervical spine and the orofacial region, pain in either structure (orofacial or cervical spine) can trigger motor adaptations in the cervical muscles as well as masticatory muscles. In the cervical spine, an increased activity of the superficial muscles (SCM and scalene muscles) as well as a decrease in the fatigability of the flexors and extensors muscles of the cervical spine and reduced strength in the cervical muscles has been observed in the presence of pain. However, these changes have not been investigated in patients with TMD and thus it is not known if patients with TMD present with changes of motor behavior in the cervical muscles in the presence of pain.

Thus, this project was divided in two parts: first, it was necessary to scrutinize the literature in order to identify gaps of knowledge as well as areas that needed better quality research and second, according to these findings to carry out clinical research to answer part of this need. It was felt that an objective evaluation of the cervical musculoskeletal impairments through the use of validated and objective clinical tools and tests along with electromyographic (EMG) assessment specifically looking at alterations in head and cervical posture, maximal cervical flexor muscle strength, endurance of the cervical muscles, and performance of the cervical flexor muscles (as evaluated by the CCFT) as well as the presence of neck disability in patients with TMD could clarify the cervical involvement in the symptomatology of patients with TMD. Additionally, this evaluation could open an area of study to treat these alterations through improvement in motor control of cervical muscles in patients with TMD.

1.2 OBJECTIVES OF THE STUDY

The overall objective of this project was whether there may be cervical involvement in patients with TMD, specifically looking at alterations in posture, maximal cervical muscle strength, endurance of the cervical muscles, and performance (as evaluated by the craniocervical flexion test) of the cervical flexor muscles as well as the presence of neck disability.

The specific objectives of this project were:

1. To determine the evidence and its quality in terms of the association between cervical spine and craniofacial pain.

2. To determine the evidence and its quality in terms of the the association between head and cervical posture and TMD.

3. To determine whether there was a relationship between neck disability measured using the Neck Disability Index (NDI) and jaw disability measured through the Jaw Function Scale (JFS).

4. To determine whether patients with TMD (i.e. myogenous and mixed types) had different head and cervical posture measured through angles

commonly used in clinical research settings, when compared with healthy individuals.

5. To determine whether there was a difference in maximal cervical flexor strength in subjects with TMD (i.e. myogenous and mixed types) when compared to healthy subjects.

6. To determine whether patients with TMD (i.e. myogenous and mixed TMD types) had reduced endurance (measured through the holding time in seconds) of the cervical flexor muscles at different levels of muscular contraction (25%, 50%, and 75% maximum voluntary contraction [MVC]) when compared to healthy subjects.

7. To determine, through electromyographic evaluation, whether patients with myogenous TMD and mixed TMD had altered muscular activity in the superficial cervical muscles (i.e. sternocleidomastoids and anterior scalenes) expressed as higher electromyographic activity when executing the craniocervical flexion test compared to normal control subjects.

8. To determine, through electromyographic evaluation, whether patients with myogenous and mixed TMD have greater fatigability of the cervical extensor muscles (i.e. midcervical paraspinal muscles [trapezius, capitis group, and cervicis groups]) when performing a neck extensor muscle endurance test (NEMET) compared to healthy control subjects.

1.3 RESEARCH HYPOTHESES

The following hypotheses were investigated in this study:

1. There will be a strong association between jaw disability and neck disability.

2. Patients with TMD will have altered cervical and head posture, measured through angles commonly used in clinical research settings, when compared with healthy individuals.

3. Patients with TMD (i.e. myogenous and mixed types) will have decreased maximal cervical flexor strength when compared to healthy subjects.

4. Patients with TMD (i.e. myogenous and mixed TMD types) will have a reduced endurance (measured through the holding time -in seconds) of the cervical flexor muscles at different levels of muscular contraction (25%, 50%, and 75% maximum voluntary contraction) when compared with healthy subjects.

5. Patients with TMD (i.e. myogenous and mixed TMD types) will have increased cervical muscular activity in the superficial muscles (i.e. sternocleidomastoid, anterior scalenes) when executing the craniocervical flexion test compared with normal subjects.

6. Patients with myogenous TMD (i.e. myogenous and mixed TMD types) will have greater muscular fatigability in the cervical extensors muscles

(i.e. midcervical paraspinal muscles [trapezius, capitis group, and cervicis groups]) when performing a neck extensor endurance test when compared to normal control subjects.

1.4 LIMITATIONS OF THE STUDY

This project was limited by:

1) The use of a convenience sample. Subjects with TMD were recruited from the TMD/Orofacial Pain Clinic at the School of Dentistry, Faculty of Medicine and Dentistry, and healthy subjects were recruited from students and staff at the University of Alberta.
2) The ability of the researcher to apply the same procedure for every subject. This factor was controlled by:
    a) The evaluator making sure that the same procedure was used for every subject
    b) In case of electrode placement, the references used for electrodes placement were the same for every subject following the anatomic landmarks and published guidelines.
    c) The instrumentation and place used were the same for all subjects.
    d) The same evaluator assessed all subjects.
    e) The instructions given to the subjects during each of the procedures were the same.
3) The reliability of electromyographic (EMG) equipment.
4) Potential researcher bias when reading and analyzing the results (even if the measurements were concrete). The sources of bias could be the potential error

when analyzing the EMG signal. This was controlled as much as possible by applying the same blinded procedure to analyze all data.

5) The ability of the researcher to determine patients diagnoses. The TMD diagnosis was only performed based on clinical examination, following the guidelines established by the RDC/TMD criteria.
6) This research is applicable only in the following conditions:
   a) Under the same conditions and procedures performed in this study.
   b) Only for the muscles described and analyzed.
7) The studies used in this project were cross-sectional in nature

1.5 DELIMITATIONS OF THE STUDY:

This project was delimited to:

1. Subjects having normal craniomandibular systems with no known pathology (healthy control group).
2. Patients with myogenous and mixed TMD (patient groups).
3. Female subjects between 18 and 50 years old.
4. The evaluation of the cervical involvement, specifically looking at the evaluation of cervical and head posture, maximal cervical muscle strength, endurance of the flexor and extensor cervical muscles, and performance of the cervical flexor muscles (as evaluated by the craniocervical flexion test) as well as the presence of neck disability in patients with TMD when compared with healthy subjects.

1.6 ETHICAL CONSIDERATIONS

This research was performed while maintaining total privacy of the subjects.

Consent from the Ethics Committee of the University of Alberta and informed consent from the subjects was obtained before individuals were enrolled in this study.

1.7 GENERAL LITERATURE REVIEW

1.7.1 TEMPOROMANDIBULAR DISORDERS

1.7.1.1 CLASSIFICATION

Several classification systems have been used in epidemiological studies to define TMD. However, not all of them have been validated or tested for reliability and responsiveness. The present accepted criteria for diagnosing TMD is the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD). The RDC/TMD is a guide that provides clinical researchers with a standardized system to use for examining, diagnosing, and classifying the most common subtypes of TMD with a clear face validity and criterion validity[100]. It was introduced in 1992 and has been widely used in clinical research settings around the world where TMD and facial pain are managed. This guide has been recommended as a model system for the standardization of the investigation in diagnosis and classification of any chronic pain condition. This guide is divided into two sections: Axis I: clinical TMD conditions; and Axis II: Pain-related disability and psychological status.[101]

The main objective for creating this tool was to maximize reliability across research settings and to minimize variability in examination methods and clinical judgment that might influence the classification process.[101] In general, this guide gives information related to diagnosis, evaluation methods; clarification of concepts, terminology, and the evaluation of psychological aspects in TMD. The RDC/TMD is not an index to measure the severity of craniomandibular disorders, but rather is used to help clinicians with diagnosis. According to the authors, RDC/TMD is the only available diagnostic system that is empirically-based and has been translated into 18 languages and is the common diagnostic method used by the member consortium of RDC/TMD –based international researchers.[102]

List and Dworkin[103] analyzed the utility of the RDC/TMD in the Swedish population. They concluded that the RDC/TMD contains good definitions useful for diagnosis of the most common forms of TMD in two very different settings (Sweden and the USA). They concluded that this guide is a valuable tool for classifying TMD patients and allowing multicenter and cross-cultural comparisons of clinical findings. Moreover, Dworkin et al.[104] evaluated the use of this guide in assessing non physical aspects (Axis II) of this scale and found that RDC/TMD had good reliability, validity, and clinical utility for the axis II measures of depression, somatization, and graded chronic pain.

Some recent studies have demonstrated the good reliability of the RDC/ TMD in different settings, not only in determining signs and symptoms [105] but also in making reliable diagnoses [102]. Wahlund et al.[106] found good to excellent reliability (kappa >0.78) for each of the RDC/TMD major groups. John et al.,[102], in a recent multicenter study, considering different centers around the world (San Francisco, Portland, Singapore, Sydney, Amsterdam, Heidelberg, Zurich, Naples, Linkoping, Malmot), found that the RDC/TMD had a fair to good reliability for determining myofascial diagnoses (ICC=0.75) with or without limited mouth opening, disc displacement with reduction (ICC=0.61), and arthrogenous pain/osteoarthrosis (ICC=0.54). Nevertheless, variability among centers was high. The positive agreement among different diagnoses was higher for more prevalent diagnoses. Myofascial pain reached a positive agreement between 56-72%. The negative agreement was high regardless of the type of diagnosis. The median of negative agreement across centers was 89% or higher indicating that raters agreed highly when a diagnosis was not present.[102]

According to Drangsholt and LeResche,[100] there is no “gold standard” for diagnosing temporomandibular disorders. The best method until now has been a comprehensive medical history, physical examination, and selective use of imaging when joint structures are affected. Thus, diagnoses obtained through the RDC/TMD are from a conceptual point the best way to classify TMD and are strongly supported in TMD clinical and research practice.[102]

The main classification categories described by the RDC/TMD Axis I diagnosis are the following:[101]

Group I: Myofascial Pain Disorders

a. **Myofascial pain without limited mouth opening (Ia):** This myofascial pain is characterized by a report of pain or ache in the jaw, temples, face, preauricular area, or inside the ear at rest or during function; pain reported by the subject in response to palpation of three or more of the following muscle sites (right side and left side count as separate sites for each muscle): posterior temporalis, middle temporalis, anterior temporalis, origin of masseter, body of masseter, insertion of masseter, posterior mandibular region, submandibular region, lateral pterygoid area, and tendon of the temporalis. At least one of the painful sites must be on the same side as the complaint of pain.

b. Myofascial pain with limited mouth opening (Ib): This category includes myofascial pain as defined in Ia; plus pain-free unassisted mandibular opening of <40 mm; or a maximum assisted opening (passive stretch) of ≥ 5 mm greater than pain-free unassisted opening.

Group II: Temporomandibular Joint Disc displacement

a. **Disc displacement with reduction (IIa):** This category is characterized by reciprocal clicking in the TMJ (click on both vertical opening and closing that occurs at a point at least 5 mm greater interincisal distance on opening than on closing and is eliminated on protrusive opening), reproducible on two of three consecutive trials; or clicking in TMJ on both vertical range of motion (either opening or closing), reproducible on two of three consecutive trials, and click during lateral excursion or protrusion, reproducible on two of three consecutive trials.

b. **Disc displacement without reduction,** acute form (IIb), and chronic form (IIc)

c. IIb. **Disc displacement without reduction, with limited opening** is characterized by a history of significant limitation in opening; maximum unassisted opening ≤35 mm; passive stretch increases opening by ≤4 mm over maximum unassisted opening; contralateral excursion <7 mm and/or uncorrected deviation to ipsilateral side on opening; absence of joint sounds or presence of joint sounds not meeting criteria for disc displacement with reduction.

d. IIc. **Disc displacement without reduction, without limited opening:** is characterized by a history of significant limitation of mandibular opening; maximum unassisted opening >35 mm; passive stretch increases opening by 5 mm or more over maximum unassisted opening; contralateral excursion ≥7 mm; presence of joint sounds not meeting criteria for disc displacement with reduction; In those studies allowing images, imaging conducted by either arthrography or magnetic resonance imaging reveals displacement of disc without reduction.

Group III: Temporomandibular Joint (TMJ) Degenerative Disease Disorder

e. **Arthralgia (IIIa):** This category is characterized by pain in one or both joint sites (lateral pole and/or posterior attachment) during palpation; one or more of the following self-reports of pain: pain in the region of the joint, pain in the joint during maximum unassisted opening, pain in the joint during assisted opening, pain in the joint during lateral excursion; for a diagnosis of simple arthralgia, coarse crepitus must be absent.

f. **Osteoarthrosis with joint pain (IIIb):** This category is characterized by arthralgia as defined in IIIa; plus either coarse crepitus in the joint or radiological signs of arthrosis.

g. **Osteoarthrosis without joint pain (IIIc):** This category is characterized by absence of all signs of arthralgia; although the presence of either coarse crepitus in the joint or radiological signs of arthrosis helps with the diagnosis.

The guidelines of the RDC/TMD are too extensive to be shown in this section, but it is necessary that these are consulted each time clinicians plan to evaluate patients who have TMD.[101] Currently, they are the basis to any clinical evaluation procedure of TMD.

1.7.1.2 EPIDEMIOLOGY

Epidemiology has been defined as the study of the distribution, determinants, and natural history of disease in populations.[107] This science helps to understand the disease process. Epidemiologic studies determine those factors most valid for determining the correct diagnosis. TMD are characterized by 1) pain in the joints and /or jaw muscles, 2) clicking or sounds in the temporomandibular joint (TMJ), and 3) alterations in mobility of the jaw (these 3 signs are called cardinal points).

TMD affected about 20 millions adults in United States and 450 millions adults around the world in 1998. In addition, one in three adults will develop TMD pain in his/her lifetime. Therefore, TMD is a very common condition.[100] However, only between 1%- 3% of the population seek care for their TMD. It is estimated that in any 6 month to 1 year period, a median of 2% of people with TMD will seek treatment. This would correspond to 5,340.000 people in the US looking for treatment. Estimates from Scandinavian and other North American populations show that one quarter or one third of persons with TMD pain seek treatment during a given year.[100] However, because TMD care is not covered by insurance in the United States; many people do not seek treatment for these conditions because they can not afford it.

It has been calculated that approximately 2 billion dollars has been spent in the US due to TMD direct care.[100] Indirect costs for TMD have not been published. Nevertheless, it is known that patients with TMD have shown high levels of unemployment and decreased work effectiveness.[108] In a large population based-cross sectional and cohort study, it was shown that TMD chronic pain had a similar individual impact and burden as back pain, severe headache, chest and abdominal pain.[109]

Generally, the epidemiologic criterion that has been used to evaluate prevalence of TMD in the past was based on the three cardinal points of TMD. According to these three cardinal points, and based on the information from epidemiologic studies, it was assumed that 75% of the patients evaluated in one study performed by Rugh J.D and Solberg[110] exhibited at least one sign such as joint noise or palpation tenderness and 33 % of the non-patient population showed at least a symptom which would potentially lead the individual to seek evaluation and care. These results are in agreement with the results found by Armijo-Olivo et al.,[111] who obtained a 87% prevalence rate for a sign or symptom for TMD in their analysis of a sample of a general population in Talca, Chile, finding that the most prevalent symptom was pain in the masticatory muscles (57% of the population). Similar results were also obtained in an epidemiologic study performed in United States and Sweden [103] using the research diagnostic criteria for TMD. In a systematic review about the prevalence of TMD performed by Drangsholt and LeResche looking at studies published between 1965 and 1998, it was found that prevalence of TMD was variable. The overall prevalence of TMD found in their study in an adult population was between 3.7 to 12%.[100]

Signs and symptoms of TMD in the general population have been found to occur twice as frequently in females as in males (2:1).[112-115] However, other studies revealed that the ratio between female and male is of approximately the same[111] or 3:1. [116] According to a recent study [117], women comprised over 70% of the patients having TMD and the ratio between females and males was 2.4: 1 for arthralgia, 2.5: 1 for osteoarthritis, 3.4 for myofascial pain, and 5.1:1 for TMJ disc displacement.[117] The literature supported the fact that women are more sensitive to pain conditions, reporting more severe pain, more frequent pain, and pain of longer duration than men.[118-125] In addition, women are more prompt in seeking help than men. Therefore, it seems that women suffer more commonly of TMD and may seek care for TMD pain more often than men because their pain is more severe.[100]

The prevalence of TMD related to age has been controversial. Some authors have found that TMD increased with age,[111, 126] decreased with age[127] or followed a Gaussian shape with the greatest prevalence between 25 to 54 years of age.[128] According to Gremillion's data, the most common age group found to be affected is between 15 to 45 years of age with an average of 33.9 years.[3] Generally, the median age for temporomandibular osteoarthritis is significantly higher for those in the other subtypes, indicating the increase of bone deformation with ageing.[117]

According to data presented by LeResche[129], 25% of the community TMD cases met only the criteria for myalgia or myofascial pain, 3.3% for an internal derangement diagnosis, and 4.2% for an arthrogenous diagnosis. Most of the subjects presented with a mixed diagnosis and were classified in more than one group. Muscle and disk diagnosis was present in 8.3% while myogenous and arthrogenous diagnosis was present in 21.7%, and myogenous, arthrogenous and disk displacement diagnosis was found in 7.5% (Table 1-1).

Table 1-1. Prevalence of TMD among Clinical and Community Cases Grouping According to the RDC/TMD

Diagnosis	Prevalence %	
	Clinical	Community
Myofascial pain (group I)	**12**	25
Disc displacement (group II)	**9**	3
Arthralgia, Arthritis and Arthrosis (group III)	**6**	4
Group I and group II	**8**	8
Group I and group III	**35**	22
Group II and group III	**1**	2
Group I, group II, and group III	**18**	8
No RDC diagnosis	12	28

According to a recent multicenter study,[102] myofascial pain with or without limitation of the mouth opening was found to be the most prevalent diagnosis among centers (median prevalence of 28% for both diagnoses).[102] The arthralgia group (group IIIa) diagnosis was a less common diagnosis, having only a median prevalence of 18%. In addition, the most prevalent non-painful diagnosis found in this multicenter study was the disc displacement with reduction (median prevalence of 19%). All of these data were confirmed by Lobbezoo et al. in a another more recent review study.[130]

According to Gremillion [3], the most common sign of TMD is temporomandibular clicking which occurs in about 50% of the TMD population. Clicking sounds may indicate local irregularities in the articulating components with or without internal derangement of an anteriorly displaced disc. According to a study by Ribeiro et al.,[131] 86 % of the patients with TMD had displacement of the disc evident on magnetic resonance imaging. However, displacement of the disc does not necessarily result in a symptomatic joint and clicking may not progress to locking and joint degeneration.[132, 133]

Cervical symptoms, such as neck pain, have been found in approximately 75% of TMD patients. Moreover, 72% of these patients reported pain in other areas of the head, and the masticatory region, and 72% reported back pain.[134] In several studies by Wijer et al.,[18, 21, 82, 83, 111], symptoms of the stomatognathic system overlap in patients with TMD and CSD, and symptoms from the cervical spine overlap in the same group of patients (TMD and CSD).

1.7.1.3 ETIOLOGY

The etiology of the TMD has been studied for many years. There are many theories that try to explain the mechanisms that cause TMD. Occlusal disharmony, malocclusion, malposition or malformation of the condyle, abnormal form and position of the fossa , previous trauma , orthodontic treatment , bruxism, stress, hard diet, oral posture, sleep disorders and poor head posture have been considered as part of multiple etiologies related to the TMD.[135] For example, it has been theorized that people who have sleep disorders and people who clench or brux their teeth have a greater possibility of having TMD [135]. Another etiological example states that malocclusion precipitates TMD. However, these etiological causes do not cover all the possible explanations about TMD etiology because some patients exhibiting these factors such as malocclusion (i.e. increased overjet, lateral open bite), bruxism, or patients who have sleep disorders do not experience signs and symptoms of TMD. According to Drangsholt and LeResche,[100] many poor quality studies have tried to establish a relationship between TMD and specific factors (e.g. exogenous hormone use, self-reported bruxism, self reported poor health, evidence of somatization, depression, obsessive compulsive disorders, occlusal disharmony, malocclusion, loss of posterior tooth support, malposition or malformation of the condyle, abnormal form and position of the fossa , previous trauma , orthodontic treatment , stress, muscle parafunction, hard diet, oral posture, sleep disorders and poor head posture). Factors associated with the female gender, the number of preexisting pain conditions, and depression appear to be strongly associated with TMD. The remaining factors have failed to demonstrate a strong relationship with TMD and more research is needed to clarify their role in causing or continuing TMD pain.

Whether a factor will cause TMD or not in a patient will depend on the patient's characteristics, and based on the way that patient can keep her/his craniomandibular system balanced.[135] In the craniomandibular system, there is normally a balance between all structures involved in the functioning of this system including the teeth, the masticatory and cervical muscles, and temporomandibular joints structures as well as the psyche of the individual. This balance can be disrupted by a number of factors such as functional factors (e.g bruxism, muscle parafunction, oral posture, head and neck posture) structural factors (e.g. loss of posterior tooth support, malposition or malformation of the condyle, abnormal form and position of the fossa) and emotional factors (e.g. stress, self reported poor health, evidence of somatization, depression, obsessive compulsive disorders) acting alone or in combination, causing signs and symptoms associated with TMD.[3] Substantial progress has been made in the understanding of TMD conditions in the last 10 years. However, more rigorous research is necessary to understand the etiology and development of different types of TMD since most of the studies to date have lacked of scientific validity.

1.8 DEFINITION OF TERMS

1) **Cervical Spine Dysfunction** (CSD): is a collective term embracing a number of clinical mechanical problems of the musculoskeletal structures of the cervical spine. Pain is usually aggravated by moving the head or adopting certain head positions.[19] Neck pain is often the main symptom of cervical spine dysfunction related to acute (macrotrauma) or chronic (microtrauma) mechanisms of injury affecting the joints or periarticular tissues surrounding the cervical spine.

2) **Cervical Muscles**: These are the muscles that act at the level of the neck or cervical region.

   a) **Superficial Cervical Flexor Muscles:** for this research, superficial cervical muscles that act during the cervical flexion movement are the sternocleidomastoid and the scalene muscles.

b) **Deep cervical Flexor Muscles:** for this research, deep cervical muscles that act during craniocervical flexion are the longus colli and the rectus capitis.

c) **Extensor Cervical Muscles:** These are the muscles that act to rotate the head backwards. They include: the upper trapezius, splenius capitis, semispinalis cervicis, and longissimus capitis, and sternocleidomastoid (if the head is in some extension). At the suboccipital level, the rectus capitis posterior minor, rectus capitis posterior major, obliquus capitis superior, and obliquus capitis inferior extend the cervical spine. For this research, the EMG of the splenius cervicis, semispinalis capitis, and longissimus capitis will be measured.

3) **Muscular Performance of the Flexor Cervical Muscles:** is defined for this research as the pattern of activity or contraction performed by the cervical flexor muscles during a specific predetermined action. For the craniocervical flexion test, the expected pattern of contraction between deep and superficial muscles is that only the deep muscles (i.e. longus colli and longus capitis) will show evidence of contraction with minimal activity from the superficial muscles (i.e. sternocleidomastoid and scalenes).[61] Measuring the activity of the superficial cervical muscles (SCM and scalene muscles) could indirectly indicate the performance between deep and superficial cervical muscles.

4) **Cervical Musculoskeletal Impairments:** are defined for this research as the loss of normal function in the articular, neuromuscular and/or nervous systems of the cervical spine.[136] For this research, cervical musculoskeletal impairments are understood to occur when there is altered: cervical muscular activity (i.e. evaluated through electromyography-EMG), cervical or head posture, or cervical muscular function (strength, endurance and/or performance).

5) **Cervical Muscular Impairments:** is defined for this research as alterations of the cervical muscular strength, endurance, performance, or alterations of cervical muscular activity (EMG) of the cervical muscles.

6) **Clinical Significance:** according to Musselman,[137] a clinically significant finding is one that has a noticeable impact on the everyday life of a client or group of subjects.

7) **Craniomandibular System (CMS)**: CMS is a system comprised of the head, cervical spine, temporomandibular joint and surrounding tissues such as muscles, fascia, nerves and blood vessels. These structures are connected anatomically, physiologically, and biomechanically.[92]

8) **Co-contraction (or coactivation)**: is understood as a phenomenon that occurs when two or more groups of muscles contract simultaneously to stabilize a

segment or joint. Thus, co-contraction minimizes the effect of potential internal and external disturbances on posture, equilibrates moments at other joints, or regulates the loads of a joint.[138] According to Cholewicki et al[65], the presence of increased levels of muscle coactivation may constitute an objective indicator of impairment in the passive stabilizing system.[65]

9) **Disability:** disability expresses the impairments (i.e. negative aspects of interactions between an individual and his/her contextual factors) at the body level, activity limitations, and participation restrictions.[139] Environmental factors (i.e. physical, social and attitudinal environment) as well as the personal factors for each individual (i.e. age, gender, race, and lifestyle) determine the level of disability of individuals.

10) **Effect Size:** represents a standardized measure of change in a group or a difference in changes between two groups.[140] Effect sizes are used to determine the clinical significance of a result.[137] Interpretation of the effect size is generally arbitrary. According to Cohen,[141] effect sizes of 0.2, 0.5 and 0.8 indicates small, moderate and large effect or change respectively.

11) **Electrodes:** a device or unit through which an electrical current enters or leaves an electrolyte. The electrode is the site of connection between the body and the collection system. Electrodes have to be harmless to the subject, and

close enough to the muscle to pick up the current generated by ionic movement.[142] For this research, surface electrodes will be used.

12) **Endurance**: has been defined as: "the ability to perform low intensity, repetitive, or sustained activities over a prolonged period of time" (p.60).[143] In addition, the concept of local fatigue can be understood as "the ability of a muscle to contract repeatedly against a load (resistance), generate and sustain tension, and resist fatigue over an extended period of time" (p.60).[143]

13) **Fatigability:** will be understood as the spectral modification of the electromyographic signal characterized by a compression accompanied with an alteration in the skewness of the shape of the spectrum of the EMG signal before the muscle becomes unable to sustain a determined force.[144, 145] The analysis of the spectral domain of the EMG provides fatigue indices, which have a greater applicability for diagnosing and evaluating muscle fatigue. In this study, fatigability will be determined by analyzing the EMG activity through the measurement and analysis of the median frequency (MDF) of the EMG spectrum and the slope of the MDF of the EMG signal. During sustained muscle contraction, the power density spectrum of the EMG signal compresses toward lower frequencies. This change in EMG correlates with muscular fatigue.[146-148]

14) **Feedforward:** Has been described as anticipatory actions occurring before the sensory detection of a homeostatic disruption.[149] Feed-forward activation is one of the strategies of the CNS to regulate motor control of muscles and contribute to maintain the stability.[149]

15) **Feedback:** is a corrective response within the corresponding system after sensory detection.[149]

16) **Forward Head Position**: is defined as a chin poking position. According to Rocabado, forward head posture is considered when the head deviates forward from the optimal posture (4-8 cm from the apex of the thoracic kyphosis to the deepest point in the cervical lordosis).[92, 150]

17) **Known Referential Contraction (KRC):** is a contraction performed by each muscle being analyzed in a known position determined by the researcher. This KRC is used as a referential value for the normalization procedure when using amplitude EMG analysis. The KRC will be determined by the evaluator and will be described in detail for each experiment.

18) **Kyphosis:** is an exaggeration of the normal curve found in the thoracic spine.[151] Kyphosis will be evaluated visually through standard postural examination.[152]

19) **Masticatory Muscles:** These are the muscles that work during the mastication process. They include the superficial masseter, deep masseter, temporalis, external pterygoid, and internal pterygoid.[153]

20) **Maximal Voluntary Contraction (MVC):** is a maximal contraction performed by a group of muscles being analyzed in a known position determined by the researcher. The electromyographic activity obtained from this contraction is used as a referential value for the normalization procedure for the electromyographic data of the analyzed muscles.

21) **Mixed Temporomandibular Disorders:** The criteria used to diagnose a patient as having mixed TMD is based on clinical findings. Patient could complain of muscular symptomatology (same as myogenous TMD, see below) in addition to articular symptomatology such as painful clicking, crepitation or pain in the TMJ at rest or during function,[154] and during compression test.[155]

22) **Motor Unit Action Potential (MUAP)**: Consists of the spatiotemporal summation of the individual muscle fiber potentials. The amplitude of the individual action potentials varies with muscle fiber diameter, distance between active fiber and detection site, and electrode properties, while the duration of the potential is inversely related to the conduction velocity of the

muscle fiber. Motor units fire randomly and at different rates, each having its own amplitude, duration and waveform.[142]

23) **Myogenous Temporomandibular Disorders:** will be based on the research diagnosis criteria for muscle disorders according to Dworkin and Le Resche.[156] Patients must present with constant pain or ache in their masticatory muscles, face, and/or preauricular area or inside the ear at rest or during function. In addition to the criteria stated by Dworkin and LeResche,[101] subjects cannot complain of painful clicking, crepitation or pain in the TMJ at rest or during function,[154] and during a compression test.[155]

24) **Neuromuscular Control**: has been defined by Reinmann and Lephart[149]as: "Unconscious activation of dynamic restraints occurring in preparation for and in response to joint motion and loading for the purpose of maintaining and restoring functional stability" (p 73). Thus, motor control can extend to any aspect related to the control that the CNS exerts over muscle activation and factors that contribute to task performance.

25) **Noise:** is any unwanted signal detected alongside the wanted signal.[142] The noise can come from different sources: inherent noise in the electronics components in the detection and recording equipment, ambient noise, motion artifacts, and inherent instability of the signal[157].

26) **Posture:** Posture is defined as “the relationship between a segment or part of the body related to other adjacent segments, and the relationship between all the segments to the human body”[158]. It is an indicator of biomechanical efficacy, equilibrium, and neuromuscular coordination.[159] Human beings require a stable and balanced posture for proper human movement. The neuromuscular system is responsible for maintaining the posture of the body and allowing movement to occur.

27) **Reliability:** refers to the extent to which a test score is free from errors of measurement. [160]
    a) **Intra-rater Reliability**: repeatability of measurements taken by the same tester at different times
    b) **Inter-rater Reliability**: repeatability of measurements taken by different testers.

28) **Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD):** This is the accepted criteria for diagnosing TMD. The RDC/TMD is a guide that provides clinical researchers with a standardized system to use for examining, diagnosing, and classifying the most common subtypes of TMD with a clear face validity and criterion validity.[100]

29) **Strength/Force**: is defined as: "the ability of contractile tissue to produce tension and resultant force based on the demands place upon the muscle. p.(59-60) [143] Force is used interchangeable with strength in this research.

30) **The Normalization Procedure for Amplitude EMG**: The normalization procedure for amplitude EMG activity consists of establishing a relationship between the parameters of the EMG activity of the muscles under examination while measuring a known referential contraction (KRC) (generally maximal voluntary contraction –MVC-is used for this purpose) of the muscles that will be analyzed and the subsequent submaximal contractions measured during the procedure. Thus, all submaximal contractions registered during the procedure are related to this known referential EMG value obtained during a voluntary contraction and they are expressed as a percentage of this referential value.

31) **The Normalization Procedure for Frequency Analysis of EMG**: in order to allow comparisons between subjects, in this research, the time course of each EMG variable will be normalized with respect to the intersection of the regression line in the fatigue plot.[144]

32) **Standard Error of the Measurements**: The SEM quantifies the precision of individual scores on a test.[161] According to Harvill [162], measurement error is the difference between an examinee's actual or obtained score and the

theoretical true score. The interpretation of the SEM centers on the assessment of reliability within individual subjects.

33) **Stomatognathic System:** The stomatognathic system is an integrated and coordinated morphofunctional unit, consisting of skeletal, muscular, circulatory, nervous, glandular and dental structures, organized around the occipitoatlanto, atlanto-axial, cervical, temporomandibular, and dento-alveolar joints. This system works functionally with the digestive, respiratory, and articulatory systems, and esthetic-facial expression. It also works in concert with the senses of the taste, and touch. Suction functions, oral digestion (which includes mastication, salivation, tasting and the initial degradation of food); swallowing; verbal communication (involves, among other actions, speech, whistling and desire); oral sexuality (includes a smile, laugh, bucofacial gesticulation, a kiss, among other aesthetic-affective manifestations); alternating breathing and vital mechanisms of defense, integrated by a cough, expectoration, sneeze, yawn, sigh, exhalation and vomit, essential for the survival of individual are also part of this system.[163]

34) **The Craniocervical Flexion Test** (CCFT): is a low-load test used to evaluate the performance of the deep cervical muscles (longus colli, and rectus capitis). The craniocervical flexion consists of performing a craniocervical flexion (nodding) movement, an action that is performed by the action of the deep cervical muscles. Superficial muscles such as SCM and the scalenes normally

do not participate in this movement. The CCFT test is performed using the air filled pressure sensor which is inserted between the testing surface and the back of the neck. This air pressure sensor is pre-inflated to 20 mm Hg to fill the space without pushing the neck into lordosis. Anatomically, a contraction of the longus colli causes a subtle flattening of the cervical lordosis. The pressure sensor will detect this flattening of the cervical lordosis as a pressure increases. Any unwanted head lift or general cervical flexion will lift the weight of the neck off the sensor causing a decrease of the pressure. CCFT has content, and construct validity, and has demonstrated a good reliability in standardized settings.[61, 164-166]

35) **Temporomandibular Disorders (TMD).** TMD are also called craniomandibular disorders (CMD).[167] "TMD is a collective term that embraces a number of clinical problems that involve the masticatory muscles, the temporomandibular joint (TMJ) and associated structures"[167] p.131. Some authors include alterations in the craniocervical system such as forward head posture, neck pain, headache and CSD because researchers have found that problems related to the cervical spine exist in patients with TMD.[18, 21, 83, 168]

36) **Validity:** is a quality that is attributed to those measurements that quantify what they are supposed to and that provide a true representation of what is being measured.[160]

a) **Face Validity**: The content of a measurement seems to be measuring what it is supposed to measure [169]

b) **Content Validity**: The items of the instrument represent or reflect all the significant aspects of the construct being measure[169]

c) **Construct Validity**: refers to the scale's behaviour in relation to other related assessment tools [169]

   i) **Convergent Validity**: indicates the degree of agreement between measurements of the same trait obtained by different approaches supposed to measure the same trait.[169]

   ii) **Divergent Validity**: indicates that the results obtained by an instrument do not correlate strongly with measurements of a similar but distinct trait.[169]

1.9 CLINICAL SIGNIFICANCE

Most of the results of research in general and health research have used statistical significance to demonstrate effectiveness of an intervention or to demonstrate differences among groups in some variables of interest, or associations between variables. Statistical significance is based on hypothesis testing.[170] The null hypothesis states that there is no difference between groups or that an independent variable does not have an effect on the dependent variable. The alternative hypothesis states that groups are different or that an independent variable does have an effect in the dependent variable. After conducting the research, the statistical analysis provides a "p" value which indicates the probability that the observed data would have occurred by chance (or due to sampling variation) if the null hypothesis were indeed true.[171, 172] Therefore, statistical significance only indicates that the results did not occur by chance (which is very little information) and does not offer an indication of how crucial the change is, how important the association between variables is or how big the impact of an intervention for the clients' life is.[173-175] Statistical significance can also provide misleading results. A statistical difference between groups could be found if the sample size was large and also if the intersubjects variability was low, even though the difference between groups was not clinically important.[173] Some authors have argued that test of statistical significance is not generally useful and instead confidence intervals (CI) and measures of effect size should be the main focus of research findings since they can provide more complete information regarding the magnitude of the association between variables, change after a treatment, or difference between groups.[176] For example, CI contain all the information provided by a significant test in addition to a range of values within which the true difference is likely to lie. This information facilitates understanding of the "magnitude of the effect" by researchers and clinicians and offers more information in addition to the simple yes/no dichotomy of the hypothesis testing.[177]

A result could be clinically important but might be neglected if statistical significance was not attained due to small sample sizes or high intersubject variability. Clinical significance assessment indicates whether the results are meaningful or not. In this way, the evaluation of clinical significance can provide more useful results to health care clinicians as well as clients receiving care, facilitating the transfer of knowledge into clinical practice.[137] Some authors in the area of education,[170, 178] as well as health research areas [137, 173] have urged that research findings be reported in language that is familiar to practitioners. With the advancement of health care and the introduction of evidence based practice, researchers need to provide research information that can be used in clinical practice and demonstrate an impact in health care by affecting clinical decisions. The information provided by "p" values is insufficient to achieve these requirements. Clinical researchers providing clinical significance of research results does help to meet these requirements.

The assessment of clinical significance has been a matter of study for many years in many fields. For more than 4 decades, data analysts have recommended the use of clinical significance assessment, in addition to statistical significance.[176] The definition of clinical significance depends on many factors and perspectives (e.g. patient, pathological condition, research, clinician, policy maker, society) which make the assessment of clinical significance very complicated. Some methods used to determine statistical significance have been created in order to provide clinicians, clients and policy makers with standards of meaningful change. The most commonly used methods to determine clinical significance are "distribution-based methods" and "anchor-based methods". The distribution-based methods are based on the statistical distribution and the psychometric properties of the outcomes. The calculation of the effect size, the minimal important difference (MID), and the standard error of measurement are examples of distribution-based methods used to evaluate clinical significance. The anchor-based methods involve the clients' perspective in the assessment of clinical significance and are used prospectively.

In this project, evaluation of clinical significance of the results was performed based on the distribution-based method using the effect size (ES) (cohen d). [179] Effect size was considered important when ES≥ 0.4.[141]

Effect size has been defined by Cohen [141] as: " the degree to which the phenomenon is present in the population", so the larger the effect size, "the greater the degree to which the phenomenon under study is manifested"[141] p.10. According to Ogles,[174] ES can provide information regarding the magnitude of association between variables as well as the size of the difference between groups. Commonly, the ES is calculated by dividing the difference between group mean scores (i.e. control group and patient group; control group and intervention group; pre intervention scores and post intervention scores) by the standard deviation at baseline, by the standard deviation of the control group, or by the pooled standard deviation of the 2 groups.[180] The magnitude of the effect size has been interpreted as an index of clinical significance.[137, 170] The larger the effect size index of clinical significance is, the larger is the difference between the groups and the clinical significance of the results is larger.[137] Since effect size is a measure that can be applicable to all kinds of research issues and statistical models, [141, 170] the use of effect size as a measure of clinical significance can be used not only for research based on interventions but also for other types of non experimental research (e.g. correlational, comparative research). [171] According to Cohen, the ES can be treated as a parameter that has a value of zero if the null hypothesis is true and can take another value other than zero if the null hypothesis is false. Thus, the ES indicates the degree of departure from the null hypothesis.[141]

Cohen described 0.2, 0.5, and 0.8 as small, moderate and large effect sizes respectively.[141] In simple words, a moderate effect size is “visible to the naked eye of a careful observer”.[141] However, according to Kirk [170] and Callahan, [171] these values should be used only as guidelines and cannot be “sanctified”. In other words, when researchers or clinicians are uncertain about the clinical significance of some results, these ES values can help with that decision, however, they cannot be considered as absolute values of clinical significance in all conditions.

Clinical significance is a complex construct and has to be analyzed from different point of views such as type of pathology, clients’ perspectives of improvement, as well as society perspectives regarding impact on public safety, health care policy and cost. Thus, clinical significance assessment methods can help guiding decisions regarding the clinical importance of the results but they need to be complemented by clinical reasoning as well as clinical experience or clients’ perspectives in order to make a final decision. [171]

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2 CHAPTER 2

ASSOCIATION BETWEEN THE CERVICAL SPINE, THE STOMATOGNATHIC SYSTEM AND CRANIOFACIAL PAIN: THE EVIDENCE

2.1 INTRODUCTION

Craniofacial pain (CFP) is a term that encompasses pain in the head, face, and related structures and can originate from a variety of conditions, organs and etiologies [1]. Many etiologies and factors can be related with craniofacial pain; however, the association between the cervical spine and its structures and craniofacial pain is a topic that is still debated. There are numerous types of associations (anatomic, biomechanical, neurological, and pathological) between the cervical spine and the craniofacial region. All can give some clue to the functioning of this system and also to the symptomatology that patients feel. According to some studies, the cervical spine and its structures are related to the symptomatology felt by patients in the face and head [2-28] . However, other studies indicate that the information about this relationship is unclear and lacks foundation.[29-33] The anatomic-neurological[16, 34, 35] and biomechanical relationship between the cervical spine and the stomatognathic system (SS), according some authors [11, 18, 22, 23], is a foundation that associates the normal

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functions of the craniomandibular system (CMS) and its pathological aspects.[2, 7, 8, 36-38]

The objective of this review was to present and analyze the evidence of the associations among the cervical spine, the stomatognathic system, and craniofacial pain.

2.2 THE SEARCH METHODOLOGY

The Medline-Pubmed (1966- may week 1, 2006), Web of Sciences (1929-May 11, 2006), Cochrane Library and Best Evidence (1991-Firts quarter, 2006), Cinahl (1982 to May week 1, 2006), Health Star (1966 to April, 2006) and Embase (1988 - week 18, 2006) databases were searched for all publications related to the topic in the English and Spanish languages. The key words used in the search were cervical spine, cervical vertebrae, neck pain, neck injuries, neck muscles, craniofacial pain, orofacial pain, facial pain, temporomandibular joint pain, and temporomandibular joint disorders. Some key word variations were necessary for different databases. A total of 384 articles resulted from the database search. Relevant articles were also obtained from reference lists of the retrieved publications. Because many articles related cervical spine with craniofacial pain, articles selection was based on the following criteria: 1) any cervical problem involved with any sign or symptom in the craniofacial region such as headache, muscular pain, or temporomandibular disorders (TMD) and 2) be relevant to the association between cervical spine, stomatognathic system and craniofacial pain. Articles related directly to whiplash and head or neck trauma were excluded.

2.3 THE CLASSIFICATION METHOD

The studies were analyzed based on the adapted levels of evidence stated by Sackett et al.[39] .because they present a clear and easy method of classifying studies according the study design showing a clear hierarchy (for details see Table 2-1).

Table 2-1. Adapted Levels of Evidence Stated by Sackett et al., [39]

Level of evidence	Description
Level 1a	Systematic Reviews of Randomized control trials (RCT)
Level 1b	Individual RCTs with narrow confidence interval
Level 2a	Systematic Reviews of Cohort Studies
Level 2b	Individual Cohort Studies (prospective study – follow up with control group) and low-quality RCTs
Level 3a	Systematic reviews of case-control studies
Level 3b	Cross Sectional Studies (study one group and control of an outcome of interest in a determined time)
Level 4	Case series (study of an outcome of interest in one group of patients), poor quality cohort, and cross sectional study
Level 5	Expert Opinion (reviews, clinical experiences)

2.4 RESULTS

2.4.1 THE ANATOMIC AND BIOMECHANIC RELATIONSHIP BETWEEN THE CERVICAL SPINE AND THE STOMATOGNATHIC SYSTEM

The cranium is connected to the cervical spine through the atlanto-occipital joints. The occipital condyles articulate with the lateral masses of the atlas, which are part of the superior cervical spine. The cranium is connected to

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the jaw through the temporomandibular joints between the temporal bone of the cranium and the mandible, which contains the lower teeth. All of these structures are joined by the capsuloligamentous, muscular, vascular, lymphatic, and nervous systems.[22, 40] Craniocervical posture achieves equilibrium and stability when the eyes are in a horizontal position and the masticatory and auriculonasal planes are parallel and horizontally located. [22] The postural stability of the head and cervical spine is regulated by the action of the mechanoreceptors of the upper cervical spine. This neurological regulation works in conjunction with the muscular action of the posterior cervical muscles that maintain the head in the horizontal position. [11, 41-43]

Many factors control craniocervical posture, including the vestibular and visual apparatus, the proprioceptors of the neck, the hyoid position, and muscular activity.[23] Muscular activity includes the small muscles in the craniocervical and cervical spine, including the rectus capitis posterior major and minor, obliquus capitis superior, obliquus capitis inferior, and multifidus. In addition, large muscles such as the trapezius, splenius capitis, and semispinalis capitis work with the small muscles to maintain equilibrium. [41]

To understand the mechanisms that are necessary to maintain equilibrium and stability of the cranium and cervical spine, it is necessary to understand the mechanical function of this complex system. At the level of the craniocervical joints, a first degree lever with its rotation point located in the atlanto-occipital joints exists. Resistance is provided by the weight of the head and the center of

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gravity is located anteriorly. Power for movement and stabilization is provided by the posterior cervical muscles (e.g. the trapezius, splenius, semispinalis, and multifidus muscles), all of which work constantly to maintain stability and the position of the head, as the head has a tendency to "drop" anteriorly when in an upright posture.[22, 42] This tendency of dropping anteriorly is called "inverted pendulum behavior".[11, 43] To maintain this stability of the craniomandibular system (CMS), an equilibrium should exist between the anterior and posterior forces. Anterior forces are provided by the masticatory muscles, the supra - and infrahyoid muscles, and the anterior cervical muscles. Posterior forces are provided by the posterior cervical muscles. These muscular groups and the structures that comprise the craniomandibular system work together as a functional chain.[23] (Figure 2-1).

Figure 2-1. Craniomandibular Equilibrium

Part of the interconnection between stomatognathic system and cervical spine can be explained by the sliding cranium theory, [18] which suggests that changes in head posture are able to produce a change in the contact of the teeth by altering the position of the maxillary teeth relative to the mandibular teeth. Biomechanically, when the cranium slides forward, an extension movement in the occipitoatlanto joint occurs. At the same time, the maxillary teeth slide forward since they are joined to the cranium and, consequently, the teeth contact position shifts posteriorly to the intercuspal position. When the cranium slides backward, the reverse situation occurs. Therefore, movements in the craniocervical unit cause adaptative movements in the jaw and related structures. [11, 18, 43]

Some researchers have shown that the cervical and craniocervical postures are related to the position of the mandible and facial structures, and any intervention or modification to the craniocervical system can have an effect on the stomatognathic system and vice versa. [19, 21, 23, 44-46] For example, Moya et al.[19] in an study with 15 patients stated that when patients were treated with occlusal splints for sternocleidomastoid and trapezius spasms, the increase in the vertical occlusal dimension that occurred generated significant craniocervical extension and a decrease in the cervical spine lordosis. This observation can be explained by the fact that when the mouth opens, the head rotates in a backward direction causing a decrease in the cervical lordosis since the cervical spine biomechanically tends to move in the opposite direction to head movement.[17, 28, 47, 48] Yamabe et al. [28] confirmed in their research using 10 subjects that the backward extension of the head accompanying opening movement of the jaw increased the tension of the suprahyoid muscles while the forward flexion position of the head increased the activity of the masticatory muscles and cervical muscles in order to maintain the equilibrium of the CMS. According to studies performed by Schwarz, [49], Posselt, [20] and Preiskel, [21] head extension resulted in posterior displacement of the mandible, whereas head flexion caused the mandible to be displaced anteriorly. Later, McClean et al.[50]demonstrated that in the supine position, the initial tooth contacts were posterior to those found when the body was upright. Conversely, Makofsky, et al.[30] studied the relationship of the head on teeth contact position in 39 patients and found no relationship between forward head posture and occlusal contact pattern, demonstrating differing results from those studies mentioned previously [20, 21, 49, 50] even for studies of the same level of evidence.

Solow and Tallgren, [45] determined that the extension of the head on the cervical spine was associated with a significant mandibular retrusion. In addition, Funakoshi et al.[51] determined that craniocervical extension produced greater muscular activity in the temporalis muscle and a moderate increase in the masseter muscle. McClean [52] found that masseter muscle along with upper trapezius muscle decreased their activity in habitual posture when compared with forward head posture. In addition, forward head posture required more masseter muscle activity when compared with a corrected posture (21.7% MVC)(in sitting position).[52] Slouched posture increased the activity of masseter muscle to 21.9% MVC in a standing position compared with the other studied postures (corrected posture, habitual posture and forward head posture). The author described this increase as the only clinically relevant difference between postures obtained by comparing the masseter muscle with the cervicobrachial muscles. Svensson et al.,[53] found increased activity of the masseter muscles (left and right) when the head was moved backwards (head back position) compared with head in the resting position.

Goldstein et al.[12] concluded that alterations to the anteroposterior head and neck posture influenced the trajectory of mandibular closure in a normal population. Visscher et al. [46] found that head posture also influenced the intrarticular distance in the temporomandibular joint. However, these changes were too small to be clinically relevant. The detailed analysis of the level of information provided by the previous studies is shown in Table 2-2.

Table 2-2. Analysis of Studies Referring to Anatomic and Biomechanical Connection between Cervical Spine and Stomatognathic System.

First Author	Study design	Level of Evidence	Remarks
Funakoshi (1976)[54]	**Descriptive Case series**	**Level 4**	Sample: 320 students, descriptive experience Results: Jaw muscles responded to changes in the head position Comments: no quantification of electromyography, only visual description. Results with Caution
Gillies (1998)[11].	**Descriptive**	**Level 5**	Expert Opinion
Goldstein (1984). [12].	**Descriptive Case series study**	**Level 4**	Sample: 12 normal subjects, small sample size, one group pre/post test, descriptive experience Results: alterations of anteroposterior head and neck posture appear to have an immediate affect on the trajectory of mandibular closure in normal population
Kohno (2001) [17].	**Descriptive Case series**	**Level 4**	Sample: 5 subjects, small sample size, pilot study Results: during mouth opening the head moves backwards and during closing in the opposite direction. Comments: External validity is questionable
Makofsky (1989)[18]	**Descriptive**	**Level 5**	Expert Opinion
Makofsky. (1991).[30].	**Descriptive One group pretest/posttest study**	**Level 4**	Sample size: 39 subjects, descriptive experience Results: There is not a relationship between forward head posture and occlusal contact pattern.
McLean(1970[50].	**Descriptive Case Series**	**Level 4**	Sample: 14 volunteers, small sample size, descriptive experience Results: the resting position of the mandible appears to be influenced by the position of the body in space.
Moya (1994) [19].	**Descriptive Case series**	**Level 4**	Sample: 15 subjects with the trapezius and the ECM spasms, descriptive experience Results: Cephalometric analysis showed that the splint caused a significant extension of the head on the cervical spine.
Posselt(1952) [20]	**Descriptive**	**Level 5**	Expert opinion
Preiskel (1965) [21].	**Descriptive Case series**	**Level 4**	Sample: 10 subjects, descriptive experience Results: Postural position of the mandible may vary with head position

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Rocabado (1979).*[22]*	**Descriptive**	**Level 5**	Expert opinion Book
Rocabado (1983)[23].	**Descriptive**	**Level 5**	Expert opinion
Schwarz, (1928). [49].	**Descriptive** **Cases series**	**Level 4**	Expert opinion Clinical experience
Solow (1976).[45].	**Descriptive**	**Level 5**	Expert opinion
Visscher (2000) [46].	**Descriptive** **Case series (no control group)**	**Level 4**	Sample: 10 healthy subjects, small sample size, descriptive experience Results: Head posture influences intrarticular distance in the temporomandibular joint. However, these changes are relatively small. So, no clinically relevant
Yamabe (1999). [28].	**Descriptive** **Case series**	**Level 4**	Sample: 10 healthy males, small sample size, descriptive experience Results: the head sagittal movements (flexion and extension) often accompanied the jaw open-close movements.

2.4.2 The Neurological Relationship among the Cervical Spine, the Craniofacial Region and Craniofacial Pain:

The neuroanatomic relationship between the cervical spine and orofacial pain is provided by the interconnection between the trigeminal nerve and the first cervical nerve roots. Studies in animals have supported this connection. [16, 35, 55-58] The trigeminal nerve (cranial nerve V) is a mixed nerve, having both sensory and motor functions. The principal trigeminal sensory nucleus is located in the pons. This nucleus communicates with the thalamus via two paths: the ventral (the medial lemnisco tract) and the dorsal (the spinothalamic tract). The spinal nucleus of the trigeminal nerve consists of three parts: the pars oralis, pars interpolaris, and pars caudalis. The pars caudalis starts at the level of the obex (or medulla oblongata) and extends caudally without interruption to become continuous with the grey matter of the dorsal horn of the spinal cord (Figure 2-2). At this level, the sensory fibers from the superior cervical nerve roots synapse

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with sensory nerve fibers from the descendent trigeminal tract, which descends along with additional fibers from the VII, IX and X cranial nerves, as far as the second cervical segment (C2) with some portions reaching as far as the fourth cervical level (C4), causing a path of interconnection between the neck and head. [59, 60] This region is called the trigeminocervical nucleus. Although it is not a nucleus in a classical sense, it is defined as a nucleus due to its afferent fibers. The trigeminocervical nucleus could thus be viewed as the nociceptive nucleus for the entire head and upper neck.[61] Innervation of all facial and masticatory muscles and the temporomandibular joint (TMJ) could therefore be influenced by this interaction (Figure 2-2). At the level of the trigeminocervical nucleus, there is an overlapping pattern of ramification of primary afferent fibers coming from various peripheral nerves. For example, pain from the occipital area, the dura mater, and the vertebrobasilar arterial tree may travel in the first, second and third cervical nerves, and terminating at the common second –order neurons in this nucleus. [62] Also, the communication between the trigeminal nerve and the first three levels of the cervical spine is so close that they merge into a single column of gray matter, and as a result, they are not differentiated anatomically, functionally, or pathologically. [16]

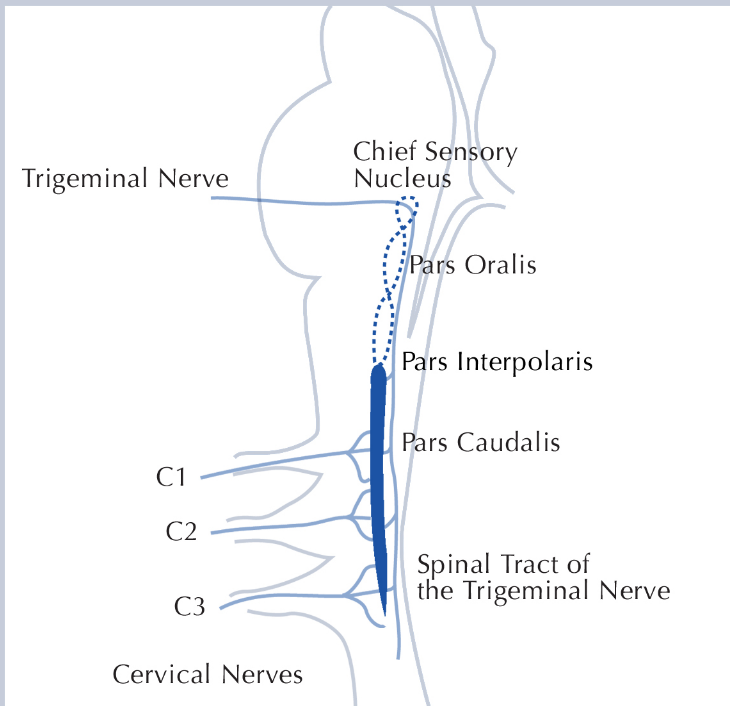

Figure 2-2. The Trigeminocervical Nucleus and Neurological Connections

This convergence, as mentioned previously, is the foundation of referred pain in the head and the upper neck. Nevertheless, the reference pattern is more common in the region innervated by the ophthalmic branch instead of the maxillary or mandibular branches since the maxillary and mandibular afferents in the spinal tract of the trigeminal nerve do not extend as far caudally into cervical segments as do the ophthalmic afferents. [60, 63]

Another finding concerning the trigeminal nerve is that at least 50% of the caudalis nociceptive neurons receive convergent afferent inputs from the upper cervical spine nerves as well as from the orofacial afferents, causing some expansion of the neuronal field of the trigeminal nerve neurons into areas that may include cervically innervated structures which could be a source of overlapping symptoms felt by patients. This convergence was demonstrated by Sessle et al.[35] in cats. They reported that inputs from different types of afferents (the skin of the mucosal areas of the mouth, tooth pulp, tongue muscles, larynx, temporomandibular joint and neck) converge in the caudalis nucleus of the trigeminal nerve. Also, these authors demonstrated that stimulation of high-threshold afferents from the jaw and tongue muscles as well as the neck muscles excited wide dynamic–range neurons (WDR), low-threshold mechanoreceptive, and nociceptive specific (NS) neurons in the caudalis nucleus. These neuroplastic changes involving the trigeminal nerve and the cervical afferents converging within the subnucleus caudalis has demonstrated the connection between the craniofacial and facial tissues. [61, 64]

In addition, some current experiments, also in animals, have studied the involvement of the trigeminal nucleus in pain in the craniofacial region and its relationship with cervical structures. Yu et al. [58] studied the effects of the application of inflammatory irritant mustard oil into rat's temporomandibular joints (TMJ) on jaw and neck muscles activity. The irritation of the TMJ caused an increase in the activity of the masticatory muscles as well as the activity of cervical muscles. However, the increase in the activity of the cervical muscles did not reach statistical significance. Conversely, another experiment on cats[55] demonstrated that bradykinin injected into the temporomandibular joint, through stimulation of nerve endings in the TMJ, changed the sensitivity of muscle spindles in dorsal muscles. [55] The authors of this study concluded that the reflex connections between the TMJ nociceptors and the fusimotor-muscle spindle system of the dorsal neck muscles might be involved in the pathophysiological mechanisms responsible for the sensory-motor disturbances in the neck region found in TMD patients. Hu et al.[65] also found that stimulation of cervical paraspinal tissues by an inflammatory irritant (mustard oil), resulted in an inflammatory response in the paraspinal tissues and increased EMG activity in the masticatory muscles as well as the cervical muscles in rats. [65] Bartsch and Goadby [66] found that stimulation of nociceptive afferent C-fibers of the dura mater (innervated by the trigeminal nerve) led to an increase in the activity and extended the size of cutaneous trigeminal and cervical receptive fields, suggesting that dural stimulation could lead to a central sensitization of nociceptive convergent second-order neurons receiving cervical input. This mechanism might be involved in the referral of pain from the trigeminal nerve areas to cervical structures and contribute to the clinical presence of cervical hypersensitivity seen in migraine or headache patients. [57]

Another source of referred pain from the cervical spine to the head is provided by the innervation coming from the upper cervical nerves roots. [60, 61, 67, 68] (Table 2-3) The atlantooccipital joint is innervated by the C1 ventral ramus and the lateral atlanto-axial joint by the C2 ventral ramus, while the C2-C3 zygapophysial joint are innervated by the C3 dorsal ramus. All three upper cervical spine nerves intermingle at multiple segments and converge with the trigeminal afferents on cells in the dorsal grey column of the C1-C3 segments. Due to this convergence, pain from any of the upper three cervical synovial joints could be perceived in the same region and referred to the occiput and to regions innervated by the trigeminal nerve. [3, 8, 67-72] Another origin of CFP could be the dura mater, which could cause headache due to the application of tension and/or pressure. The cranial dura mater is innervated by the trigeminal, vagus, and the hypoglossal nerves, as well as the upper cervical nerves. Hack et al. [73] found that there was an anatomic connection between the rectus posterior minor muscle and the dura mater; and as a result, contraction of the rectus posterior might cause tension in the dura mater and leading to a headache.

Table 2-3. Innervation Provided by Upper Cervical Nerves (C1, C2, and C3) to Different Structures

Structures	C1	C2	C3
Tissues	• Sensory information to deep suboccipital tissues. • Vertebral internal carotid • Paramedian dura of the Posterior cranial fossa	• Skin of the occiput, transverse ligament of Atlas, and membrane tectoria. • Vertebral internal carotid • through its sinuvertebral nerve, innervates the paramedian dura	• Atlantoaxial ligaments and the dura mater of the spinal cord and clivus. • Vertebral internal carotid.
Muscles	• Sensory of cervical prevertebral muscles (longus capitis, longus cervicis, rectus capitis anterior, lateralis, ECM, and trapezius.	• Major part of the upper neck muscles, splenius capitis, semispinalis capitis, and longissimus capitis	• The splenius capitis, splenius cervicis, and longissimus capitis. • The deeper branch supplies semispinalis cervicis and multifidus. • The superficial branch innervates the semispinalis capitis.

Joints	• Atlantooccipital joint • Median atlantoaxial joint.	• Atlantoaxial joint and through its sinuvertebral nerve innervates the median atlantoaxial joint.	• C2-C3 zygapophysial joint. • C2-C3 disc.

2.4.3 THE CERVICAL JOINTS, THEIR NERVES, AND REFERRED PAIN TO THE CRANIOFACIAL REGION

Neck and head pain can result from dysfunction of the medial and lateral atlanto-axial, the atlantooccipital and, particularly the C2-C3 and the C3-C4 zygapophyseal joints[3, 7, 38, 64, 74]. Radiographic studies fail to show specific characteristics in patients diagnosed with cervical headache. However, local anesthetic blocking of the zygapophysial joints, or their innervation from nerve roots, alleviates headaches in most patients.[2, 62, 69, 75] (Details about cervical spinal nerves and innervated structures are provided in Table 2-3).

Bogduk and Marsland, [2] in a study with 10 patients, evaluated the relief of headaches caused by blocking of the third occipital nerve. Their theory was that the third occipital nerve innervated the C2-C3 cervical zygapophyseal joints, and by blocking this nerve, the symptomatology presented by these patients as occipital or suboccipital headaches could be alleviated. They found that most of the subjects felt their pain was alleviated (7 of 10) resulting in a 70 % success rate. All subjects who complained of occipital and/or suboccipital headaches associated with pain radiating to the forehead or related regions experienced alleviation of pain. However, the duration of this blocking lasted only a few hours, and it had to be repeated if pain was to be continually alleviated.

In another study performed by Bogduk and Marsland [3] evaluating pain relief in 24 patients with neck pain, it was found that patients who complained of headache in addition to neck pain had pain relief when the third occipital nerve , the greater occipital nerve, or the atlantoaxial joint were blocked. Interestingly, these authors found that the C2-C3 sensory level pattern of normal subjects, which was located in the upper cervical region and extended at least to the occiput, extended further into the head, toward the ear, vertex, forehead, or eye in symptomatic patients. As well, the C3-C4 sensory pattern was located over the posterolateral cervical region, extending cranially as far as the occipital region. These results help to confirm that some symptoms of the cervical zygapophyseal joint from the C2-C3 and C3-C4 can be referred to the head and part of the face.

Another study supporting the concept that pain is referred from the cervical joints to the head was performed by Dreyfuss et al.[7] who evaluated the pain patterns of the atlantooccipital (AO) and atlantoaxial (AA) joints by injecting a contrast medium (iothalamate meglumine) into the respective joints in order to cause capsular distension and pain. They analyzed the responses of 5 volunteers and described their pain patterns as a "dull," deep ache," heavy pressure," or like "a hang-over". The atlantoaxial patterns were more stable with less variety than the atlantooccipital patterns; however, the referral pain patterns and their intensity were greater in the atlantooccipital than atlantoaxial joints. The pain provoked by injection was primarily referred to the suboccipital and occipital regions, but did not reach the vertex of the skull. The obtained pain patterns of these joints in normal subjects coincided with that found in clinical practice. The pain pattern obtained was usually suboccipital, but also spread towards the frontal, and slightly anterior to the vertex. Laterally, it was close to but did not include the ear. This study provided preliminary evidence that the atlantooccipital and atlantoaxial joints of the upper cervical spine are capable of generating head and neck pain. This pattern, however, clearly did not extend to the facial zone. Moreover, these tests were performed in only few subjects (5 subjects), and the studies lacked scientific rigour. Thus, although the studies indicate an interesting trend, the extrapolation of these results should only be made with caution.

Dwyer et al.[8] evaluated the patterns of referred pain of the zygapophyseal joints of the cervical spine in five healthy volunteers. They obtained pain patterns similar to those reported by patients. In their study, the C3-C4 and C5-C6 patterns were virtually identical to those found by Bogduk and Marsland [3] in a study of patients whose pain was alleviated by medial branch nerve and intrarticular blocks of these joints. The referred pattern from the C2-C3 joint observed by these authors resembled the distribution of pain reported by patients with headaches stemming from the C2-C3 joints [2] as reported by Dreyfuss et al.[7] However, the difference between these patterns in asymptomatic vs. symptomatic people was that the pain referral pattern was more extensive in symptomatic patients than in asymptomatic subjects, suggesting that referral patterns generated by provocation in asymptomatic subjects were reflective of a principal region (core region) of the typical referred pain in the symptomatic state. The major extension of pain could be explained because patients had a higher level of pain intensity, perhaps greater sensitization of the tissues, and may also have had a cognitive response, which could result in sensations being in a wider area. However, it is noteworthy that pain in the referred zones could occur with other pathological conditions (i.e. discs, muscles, nerves problems) and these patterns could overlap with pain caused by others structures such as the C1-C2 nerve roots, the greater occipital nerve, the suboccipital muscles, the upper cervical ligaments, and the more inferior synovial joints (C4-C5)[7]. Although their sample size was small due to ethical considerations, they found that these joints could cause a pain referral pattern that did not correspond to dermatomes or to disc pain patterns. This finding was verified later by the same authors [70] using a group of symptomatic patients (10 subjects). According to the previous map obtained from healthy volunteers, they evaluated a group of patients and blocked the suspected zygapophyseal joint levels that might cause the referral pain pattern. The results of diagnostic-therapeutic blocks were positive in most patients and confirmed the diagnosis performed by the clinicians. The pain felt by the patients was alleviated by the blocks. Also, the authors realized that the patterns presented by patients in this study were more extensive than those in normal individuals, and the pain reached beyond the core area, overlapping into adjacent areas, a finding that was in agreement with the results found previously[8].

Another study [76] evaluated the effect of sterile water injection on the greater occipital nerve in patients with headache. The authors discovered that this procedure could cause pain in the area supplied by the greater occipital nerve and in areas innervated by other nerves, mainly those innervated by the ipsilateral trigeminal nerve, a finding that coincided with the clinical manifestations of patients with headaches. Thus, a stimulus arising from the neck could trigger ipsilateral headaches projecting into the trigeminal areas.[76]

Aprill et al. [38] concluded that patients who presented with occipital headache felt relief of their pain as a result of blocking the lateral atlanto-axial joints, which demonstrated that the clinical characteristics of the pain could be due to atlantoaxial problems. Moreover, the results obtained when the occipital nerve was blocked in patients with occipital neuralgia showed all patients reporting a minimum of 80% acute pain relief after injection, and several had 100% relief.[75] The results of all previous studies related to the involvement of the zygapophyseal joints in the presence of craniofacial pain and head pain were supported by Fukui et al., [74] who reproduced headache and cervical symptoms in 61 patients by injecting a contrast medium into the cervical joints (C0-C1[cranium-atlas] to C7-T1) or by electrical stimulation of the dorsal rami (C3-C7). They found that pain in the occipital region was referred from C2/C3 zygapophyseal joints, while pain in the upper posterolateral cervical region was referred from C0/C1, C1-C2, and C2-C3. Pain in the upper posterior cervical region was referred from C2/C3, C3/C4, and in the middle posterior cervical region from C3/C4 and C4/C5. In addition, pain in the suprascapular region was referred from C4/C5 and C5/C6, pain in the superior angle of the scapula from C6/C7, and pain in the mid/scapular region from C7/T1. An analysis of the information related to the cervical joints and craniofacial pain is provided in Table 2-4.

Table 2-4. Analysis of Studies Referring to the Connection between Cervical Joints, their Nerves, and Craniofacial Pain

First Author/year	Study Design	Level of Evidence	Remarks
Aprill (2002).[38]	**Descriptive Case series (no control group)**	**Level 4**	Sample: 34 patients with headache symptoms underwent to lateral atlantoaxial block. Results: 21 patients obtained total relief of symptoms (62% success)
Aprill (1990)[70].	**Descriptive Case series (no control group)**	**Level 4**	Sample: (10 patients with neck, head, shoulders and upper limb pain). Diagnostic study through anesthetic blocks of the cervical joint. Results: 80 % diagnostic agreement between clinicians confirmed by blocks. Pain patterns from cervical joint were confirmed.
Bogduk (1986)[2].	**Descriptive Case series (no true control group).**	**Level 4**	Sample: 10 patients with occipital and suboccipital headache underwent third occipital block injection Results:7 of 10 patients relief their symptoms after third occipital block (70% success) Comments: Case series (no true control group). However , control blocks in different joints without relief of symptomatology in 5 patients acted as control
Bogduk (1988)[3].	**Descriptive Case series (no control group)**	**Level 4**	Sample size : 24 subjects with neck pain and 14 of them headache symptoms Diagnostic block were used Results: 18 patients experienced relief of their pain after blocking (72 % success). Pain patterns were obtained from these patients and also the relief of the symptoms after blocks of the specific joints.
Dreyfuss (1994) [7]	**Descriptive Case series (no control group)**	**Level 4**	Sample: 5 healthy volunteers Intraarticular injections of atlanto-occipital and lateral atlanto-axial joints to determine pain pattern of these joints were made Results: Pain patterns of these joints were obtained
Dwyer. (1990)[8].	**Descriptive Case series (no control group)**	**Level 4**	Sample: 5 volunteers (small sample size) Results: Pain pattern from cervical joints were obtained

Fukui (1996)[36]	**Descriptive Case series (no control group)**	**Level 4**	Sample: 61 patients (181 joints and 62 dorsal rami) who had occipital, neck and shoulder pain underwent cervical zygapophysial joint injection stimulation and the dorsal rami. Results: pain patterns were obtained from this study
Piovesan (2001) [76].	**Descriptive Case series**	**Level 4**	Sample: 3 volunteers humans, small sample size Clinical experience Results: Reproduction of headaches symptoms after injection over the greater occipital nerve.

2.4.4 Cervical Muscles, Myofascial Pain Syndrome (MFPS), and Craniofacial Pain

Myofascial Pain Syndrome (MFPS) is defined as pain in any skeletal muscle that is derived from specific myofascial trigger points, which are highly localized and hyperirritable spots in a palpable taut band of skeletal muscle fibers.[4, 77-82] MFPS can be associated with other neuromusculoskeletal disorders and can be aggravated by mechanical stress, metabolic insufficiencies, and psychological factors[81]. Hong[81] and Simons[79] reported that some characteristics of the myofascial trigger points were: compression of a trigger point could elicit local pain or referred pain that was similar to a patient's usual pain or might increase the existing pain; compression across the muscle fibers might elicit a local twitch response; and muscular stretch restriction.[81] MFPS can cause persistent pain which is often intense and disabling. Cervical myofascial pain has been reported to be associated with neuro-otologic symptoms including imbalance, dizziness, and tinnitus. Other neurological symptoms include paresthesias, numbness, blurred vision, and trembling. (4, 76-79) For more information, the reader is encouraged to read specific information about MFPS.[13, 81, 83, 84]

Clinical experience demonstrates that MFPS from the cervical muscles can refer pain to the facial zone.[26, 77] Active trigger points, which are spots with spontaneous pain or pain in response to movement,[81] [82] have been found in patients with headache[27, 77, 85-87] and occipital neuralgia.[13] However, diagnosis must be made very carefully considering the patient's history and related symptoms.

What is the relationship between cervical myofascial pain and pain in the cranial region? Some neuroanatomic and neurophysiological connections lead to the convergence of cervical sensory and muscle afferent inputs onto the trigeminal subnucleus caudalis. Stimulation of the supraorbital nerve and the infraorbital nerve elicits responses in the splenius and trapezius motor neurons. [88] Moreover, it has been shown that central neuroplastic changes may affect the regulation of the peripheral mechanism, leading to increased pericranial muscle activity or release of neurotransmitters in the muscle tissue. Nociception resulting from cervical dysfunction increases central sensitization, diffusing the pain in the cranial zone. [89]

Some muscles are more involved than others in pain which may be referred from the neck to the head and facial region. Muscles receiving their sensory innervation from the C1-C3 nerve roots such as the cervico-occipital muscles, the sternocleidomastoid (SCM) (supplied by the C1-C2 nerve roots), the trapezius (C1- C2 nerve roots), the splenius capitis and cervicis (C2-C3 nerve roots), and the semispinalis capitis and cervicis (C3 nerve root) could refer pain through trigger point activation to various regions of the head [4]. The referred pain from these muscles has been described by Simons [79] in specific detail. For example, the trapezius muscle refers pain to the head and neck, and the orbital and preorbital regions. The sternocleidomastoid can cause pain in the fronto-temporal region, the occiput, the vertex, the forehead, and the orbit. From the splenius capitis and the splenius cervicis, pain is commonly referred to the vertex of the head on the same side, behind the eye, and the occiput. The cervico-occipital muscles refer pain to the occiput, the eye, and the forehead. [77, 78]

Myofascial pain referred from active trigger points (TPs) in the cervical muscles may be responsible for headaches of cervical origin.[85, 90] Active TPs can usually be found in the cervical and shoulder musculature of patients with headache and orofacial pain, and their symptoms can be reproduced by pressing the TPs located in the cervical region. [26] Moreover, stimulation of the TPs during an attack of headache exacerbates or intensifies the headache.[90] Inactivation of these TPs can eliminate the symptomatology as well [4, 77, 78]. Fricton et al.[77] described the pain patterns of 164 patients diagnosed with MFPS and found the results to be in agreement with the patterns described previously by Simmons[79] confirming the concept that MFPS can cause pain in the cranial and facial region. Interestingly, it was found in an study performed by Wright [26]with 230 patients that the most common referred pain source in the craniofacial region was from palpating the trapezius muscle. [26]

Muscles acting on a joint and the joint they surround, share the same innervation. Pain referred from many upper neck muscles follows a similar pattern to that of the atlantoaxial and the C2-C3 zygapophyseal joints. The differential diagnosis between pain of articular origin and muscular pain is not clear unless a muscle injection or joint injection is performed and the relief of the symptoms occurs. Moreover, not all patients have their pain alleviated by these procedures ; thus, there may be other structures involved in the origin of pain, complicating the ability to make an accurate diagnosis even more.[4]

Additionally, many of the muscles innervated by the C1, C2, and C3 nerve roots share the feature that they attach to the skull and therefore underlie sites that are commonly tender in various forms of headache. For example, the sternocleidomastoid and trapezius muscles attach along the superior nuchal line from the mastoid process to the external occipital protuberance. Additionally, the splenius capitis attaches to the mastoid process and outer half of the superior nuchal line [60]. All of these muscles can cause pain in the skull or related areas due to their proximity to each other, not specifically due to their innervation.[4]

Trigger points (TPs) from the suboccipital muscles cause referred occipital pain in patients with occipital neuralgia.[13] Moreover, treating the trigger points of the splenius capitis and the splenius cervicis caused relief in patients diagnosed with occipital neuralgia. [13] However, the TPs from the muscles described previously and from the occipital neuralgia have the same symptomatology. Therefore, the differential diagnosis is difficult to make. Also, the treatment for neuralgia by blocking the occipital nerve is often considered to affect the TPs in suboccipital muscles. Therefore, a successful treatment injecting a TP or a nerve is not 100% successful because both could be sources of the same pain.

Jaeger et al.,[85] concluded that spontaneous referred symptoms from active myofascial trigger points might be responsible for the clinical presence of cervicogenic headaches since the symptomatology felt by the patients was reproduced by stimulation of the TPs in the cervical region. Moreover, they realized that patients who presented with MFPS also had cervical dysfunction, which might connect MFPS with cervical dysfunction and headache. On the other hand, Carlson et al.[91] found in a group of patients with MFPS of the upper trapezius that injection on the TP of this muscle caused a decrease in the pain felt in the masseter muscle and a decrease in its EMG activity in the same group of patients. This relationship between TP of the trapezius muscle injection and decrease in the activity of masseter muscle was a finding which requires more study since the sample size was small and the electromyographic (EMG) evaluation lacked clarity and showed methodological problems. Therefore, the conclusions obtained by this study must be considered with caution. Lower cervical intramuscular anesthetic injections have demonstrated good results in relief of symptoms in patients with intractable head or face pain. [86] However, this study was performed in only 7 patients, with no precision in the technique used and the muscles injected which makes the conclusion tenuous.

Antiila et al.[92] study evaluated the presence of tenderness in the pericranial and neck-shoulder region in children. They found that children with migraines had increased tenderness in the pericranial and neck-shoulder region compared with children with tension type headaches and control children patients, a result that demonstrated that the myofascial sensitivity of these muscles was increased, especially in association with severe headache. For a detailed analysis of the studies, see Table 2-5.

Table 2-5. Studies Referring to the Relationship between Cervical Myofascial Pain Syndrome and Craniofacial Pain.

Author and Title	Study Design	Level of Evidence	Remarks
Anttila (2002)[92].	**Cross sectional with randomization Children were randomly selected**	**Level 3b**	Sample: 183 children (70 migraine, 70 tension type headache and 70 control group) Power : 85% p < 0.05 Blind examination of tender points of pericranial and shoulder girdle muscles Results: Children with migraine have increased tenderness in the pericranial and neck-shoulder region than controls and tension type headache patients.
Carlson (1993)[91]	**Descriptive Case series**	**Level 4**	Sample size: 20 patients with upper trapezius trigger point and pain in ipsilateral masseter muscle Results: Trigger point injection alleviated the pain and EMG activity in masseter muscle Comments: Methodological problems in validation of the results (No normalization of EMG).
Fredriksen(1987)[90].	**Descriptive Case series**	**Level 4**	Sample: 11 patients with cervicogenic headache participated in this study Results: In 10 patients a cervicogenic attack was precipitated by firm manual pressure of a trigger point in the neck
Fricton (1985)[77].	**Descriptive Case series (no control group)**	**Level 4**	Sample: 164 patients Results: Myofascial pain syndrome patterns were obtained in this study.
Graff-Radford(1986)[13].	**Descriptive Case series study (no control group)**	**Level 4**	Sample: 3 patients with occipital neuralgia Results: Relief of symptoms after

			trigger point (TP) injection of splenius capitis.
Hong (1998)[81].	**Descriptive Review**	**Level 5**	Expert opinion
Jaeger (1989). [85]	**Descriptive Case series (no control group).**	**Level 4**	Sample: 11 patients with cervicogenic headaches Results: Patients presented cervical dysfunction and MFPS that caused the headache. After myofascial pain treatment 5 patients experienced relief of symptoms.
Mellick (2003)[86].	**Descriptive Case series (no control group)**	**Level 4**	Sample: 7 subjects Results: Relief of symptoms after lower cervical anesthetic injection in patients with intractable head or face pain.
Simons, D. (1999)[79]	**Descriptive**	**Level 5**	Expert opinion Book
Wright, (2000)[26].	**Descriptive Case series (no control group)**	**Level 4**	Sample: 230 patients with Temporomandibular Disorders Results: Myofascial pain syndrome (MFPS) pain patterns. The most common referred pain source in the craniofacial region was from palpating the trapezius muscle.

2.4.5 CERVICAL MUSCLES, EXPERIMENTAL PAIN MODELS AND CRANIOFACIAL PAIN.

The study of pain behavior through the experimental pain model has been a strategy used to simulate a painful condition and observe the motor behavior in order to study the physiology of muscle pain with time and location variables standardized.[93-96] The most commonly used and most successful method to induce pain has been the injection of hypertonic saline into muscles to model deep tissue pain in humans[95, 97-99]. The use of experimental pain has been widely accepted [93-96, 99] and has contributed to the understanding of local and referred pain, but mainly has allowed improvements in the diagnosis and treatment of the painful conditions. In fact, although experimental pain is brief, it is able to induce long term changes in the CNS of animals.[98] Some experiments investigating the sensory effect of an experimental pain model in cervical and jaw muscles have been conducted in order to understand the clinical manifestations of pain in patients with craniofacial pain. For example, Svensson et al.[100] found that glutamate injections on the splenius capitis muscle referred pain to the ipsilateral neck and occipital region, and in some subjects, toward the ipsilateral upper head and temporal region (46.15%). In one subject, the reference pattern reached the teeth and masseter region. In another study[101], hypertonic saline solution in the upper trapezius referred pain at the base of the neck in 83% of the subjects, infra-auricular zone in 50% and 42% to the retro-auricular zone. These findings were also found by Madeleine et al.,[102, 103] however, Komiyama et al.[101] found greater spread of pain to the temporomandibular joint region than Madeleine et al.[103] According to these authors, most of the subjects referring pain to the TMJ area, indicated on the anatomical map, overlapped the region where TMD symptoms usually are reported. In addition, experimental pain in upper trapezius caused a significant decrease in the mean maximum mouth opening (54 to 47.8 mm). Svennson et al[53] investigated the motor behavior during different head positions of the SCM, splenius capitis and masseter muscles when glutamate was injected into masseter and splenius capitis. They found that when glutamate was injected into the masseter, the EMG activity of the masseter as well as the activity of the SCM was increased. However, when glutamate was injected into splenius, only SCM decreased its activity. No significant changes were observed in masseter muscles although there was a trend toward inhibition during maximal clenching. The authors' conclusions highlighted the fact that jaw muscle pain can be linked to increases in neck EMG activity with the head and jaw at rest. The same group of researchers[104] investigated the effect of experimental pain of masseter and splenius muscles in the electromyographic activity and stretch reflexes of SCM and masseter muscles. They found that the normalized amplitudes of the EMG activity from the masseter and SCM were significantly higher when pain using glutamate was induced in masseter muscle as well as in splenius muscles.[104] According to the authors: "although the clinical implications of these findings are unclear, they highlight the interaction between craniofacial and cervical regions in the neuromuscular changes that may result from musculoskeletal pain in either region" (p. 1292). [104] (Table 2-6)

Table 2-6. Studies Referring to the Relationship between Experimental Muscular Pain and Craniofacial Pain

Author and Title	Study Design	Level of Evidence	Remarks
Komiyama (2005)[101]	**Cross sectional study using non painful stimulus as a control**	**Level 3b**	Sample: 12 healthy men Controlled muscular pain experience in upper trapezius muscle using hypertonic saline (6%) Results: Pain patterns from upper trapezius were obtained. Pain spread often to the infra-auricular zone. Mouth opening was significantly reduced after the experimental pain was induced in upper trapezius
Ge (2003)[102]	**Cross sectional study using non painful stimulus as a control**	**Level 3b**	Sample: 15 healthy volunteers (14 males, one female) Controlled muscular pain experience in upper trapezius muscle using hypertonic saline (6%) (unilateral and bilaterally) Results: Pain patterns from upper trapezius were obtained. Pain from bilateral injections spread often to remote areas such as temporal regions, orofacial mandibular regions, upper arms, and posterolateral neck. experimental pain was induced in upper trapezius
Svensson (2004)[53]	**Cross sectional study using non painful stimulus as a control**	**Level 3b**	Sample:19 healthy men Controlled muscular pain experience in masseter and splenius muscles using glutamate Results: Glutamate injected in masseter muscle was associated with an increase in SP EMG activity in masseter, sternocleidomastoid and splenius muscles at rest.
Svensson (2005)[100]	**Cross sectional study**	**Level 3b**	Sample:26 healthy men Controlled muscular pain experience in masseter and splenius muscles using gutamate

	using non painful stimulus as a control		Results: Pain patterns from masseter and splenius muscles were obtained. Masseter pain pattern did not extend to the neck region , however, pain from splenius muscles extended into the temporal region
Wang (2004)[104]	**Cross sectional study using non painful stimulus as a control**	**Level 3b**	Sample: 19 healthy men Controlled muscular pain experience in masseter and splenius muscles using gutamate Results: Experimental pain in Masseter and Spleinius evoked increase in the stretch reflex amplitude in both master and sternocleidomastoid.

2.4.6 CERVICAL DISCS AND CRANIOFACIAL PAIN

Based on the anatomic description of the cervical disc performed by Bogduk, [105] it is known that discs can cause pain. The sinuvertebral nerve supplies the disc at its level of entry (same level) and the disc above. Branches of vertebral nerve supply the lateral aspects of the cervical disc. Furthermore, it was found that the nerve fibers were located as deeply as the outer third of the annulus fibrosus. These findings are the foundation of clinical disc pain.[105]

Pain originating in discs of the cervical spine can cause headaches as well.[14, 37, 106] Grubb and Kelly [14] and Schellhas et al.[37, 106] obtained similar results related to the reference patterns of the cervical discs. They reproduced the symptoms through a discography procedure. Discography is a provocative diagnosic method to evaluate suspected discogenic pain because when a contrast medium is injected into the disc, the injected disc reproduces the symptomatology felt by the patient. They reported that the upper disc of the cervical spine (the C2 -C3 disc) referred pain to the upper cervical area, often extending to the occipital region and the head. Often, this pain was referred to as an occiput headache with pain sometimes referred to the level of the throat and into the ears. The C3- C4 vertebral level referred pain in a similar pattern to the

C2-C3 vertebral level. Pain was referred to the mastoid, the jaw, the TMJ, the parietal area, the occiput, the craniovertebral junction, the neck, the throat, the upper back, the trapezius muscle, the top of the shoulder, and the upper extremity and in addition, the interscapular region . According to Grubb and Kelly, [14] discs from the C4-C5 level and below cause no pain in the head region. Their pain was referred principally to the neck and the upper extremities. However, according to Schellhas et al.'s reports,[37, 106] pain from the C4-C5 disc could be felt in the mastoid, the TMJ, the parietal region, the occiput, and the craniovertebral junction. However, this data was derived from a small number of patients (40, and 10 patients respectively) compared with 160 patients studied by Grubb and Kelly. For a detailed analysis of the studies, see Table 2-7.

Table 2-7. Analysis of Studies Referring to the Connection between Cervical Discs and Orofacial Pain

First Author/year	Study Design	Level of Evidence	Remarks
Bogduk (1988)[105]s	**Descriptive**	**Level 5**	Sample size: 10 embalmed human adult cadavers Results: Anatomic description of the innervation of the cervical discs
Grub (2000) [14].	**Descriptive Case series**	**Level 4**	Sample size: 160 patients with intractable neck pain Discography procedure Results: Pain discs patterns were obtained.
Schellhas (2000) [106].	**Descriptive Case series**	**Level 4**	Sample size: 40 patients with suspected disc degeneration Results: Pain disc patterns of C2-C3 were obtained.
Schellhas (1996)[37].	**Cross sectional study**	**Level 3b**	Sample size: 10 control and 10 patients with nonlitigious chronic neck-head pain underwent discography at C3-C4 through C6-C7 after resonance imaging. Experimental and control group Results: Pain discs patterns were obtained.

2.4.7 HEAD AND CERVICAL POSTURE AND CLINICAL EVIDENCE CONNECTING THE CERVICAL SPINE WITH TEMPOROMANDIBULAR DISORDERS AS A SOURCE OF CRANIOFACIAL PAIN.

Some connections between TMD and the cervical spine have been reported. Studies have related head and cervical posture with TMD. [24, 32, 107-115] For example, Nikolakis et al.[110] demonstrated that patients with TMD presented more postural abnormalities than controls. This finding was similarly obtained by Braun[114] and Armijo et al.[113] They reported that patients with TMD had a tendency to have a forward head position and also a decrease of cervical lordosis compared to healthy controls. These findings were in agreement with those of a study performed by Lee et al., [108] who concluded that head posture was significantly different between patients with TMD and a control group. Moreover, Gonzalez and Manns, [116] in their review of head posture and the stomatognathic system, stated that forward head posture was characterized by retrognathia, which could be related to the presence of respiratory problems as well as internal derangement in the temporomandibular joint (TMJ). In addition, a close relationship between head and cervical posture improvement and the relief of symptoms of TMD was found. [27, 117] Postural exercises helped to decrease the symptomatology of patients not only at the level of the craniocervical region but also in the craniofacial region, lessening the pain in the TMJ, the masticatory muscles and in the cervical muscles [27, 117, 118]. However, some studies do not support these findings. For example, Hackney and Bade, [31] who studied the relationship between internal derangement of the temporomandibular joint and head posture, reported that patients and healthy controls had no differences in head posture. These results are in accordance with those results obtained by Visscher et al., [32] who reported no significant head posture differences in patients with TMD and cervical spine dysfunction (CSD) and healthy controls. In a recent systematic review[119] about the relationship between cervical and head posture and TMD, it was concluded that most of the studies investigating this association were of poor methodological quality; and therefore, their findings and conclusions must be interpreted with caution. Based on these findings, it is not clear that head and cervical posture is associated with intra-articular and muscular TMD. In the absence of the highest level of evidence, clinicians have to make decisions based on lower levels of evidence. More methodologically sound research will be necessary to provide clear conclusions and how to apply the findings to clinical practice. Firstly, it is recommended that investigations that study the association between TMD and head and cervical posture, provide clear diagnosis of the TMD condition in question. Secondly, there is a clear need for well-designed controlled trials investigating the association between head and cervical posture with intra-articular and muscular TMD. Analysis of the studies referring to the relationship between head and cervical posture and TMD is presented in Table 2-8.

Table 2-8 Analysis of Studies Referring to Head and Cervical Posture and Temporomandibular Disorders

Author and Title	Study Design	Level of Evidence	Remarks
Armijo-Olivo (2001)[113]. .	**Cross sectional study**	**Level 3b**	Sample: (25 subjects with TMD and 25 healthy subjects) Power: 0.94 Descriptive Analysis Experimental group and control Results: Patients with anterior disc displacement have a tendency to present a posterior rotation of the head and a decreased cervical lordosis compared with a control group.
Braun (1991)[114].	**Descriptive Cross sectional (experimental and control group)**	**Level 4**	Sample:40 asymptomatic subjects and 9 symptomatic subjects Low powered Symptomatic subjects were not representative of population Poor statistical analysis Results: Female patients with TMD presented major forward head position than female healthy controls.
Darlow (1987)[112]	**Descriptive Cross sectional study**	**Level 3b**	Sample: 30 patients with myofascial pain of masticatory muscles were compared with 30 control patients. Low powered: 0.37 Results: No significant differences in posture were found between myofascial pain patients and healthy controls
Hackney (1993) [31].	**Descriptive Cross sectional study (experimental and control group)**	**Level 3b**	Sample : 22 patients with internal derangement and 22 healthy volunteers Results: there were not differences between patients and control in head posture.
Huggare, (1992)[117].	**Cohort study Poor quality**	**Level 4**	Sample: 16 subjects with TMD and 16 asymptomatic subjects Statistical analysis not appropriate for all outcomes Results: head posture changed after treatment of patients and this could be related to a decreasing of the symptoms of TMD.
Kritsineli.(1992)[107].	**Case Series descriptive**	**Level 4**	Sample size: 40 children with primary dentition and 40 children with mixed dentition It was performed an evaluation of the TMD and malocclusion factors in these subjects and a measurement of head posture Statistical analysis unclear Results: forward head position had a significant relationship to TMD in the mixed dentition.
Lee (1995)[108].	**Descriptive**	**Level 3b**	Sample: 33 patients with TMD and 33

	Cross sectional study (experimental and control group)		healthy subjects TMD diagnosis mixed Results: The head was positioned more forward in patients with TMD than healthy volunteers
Nicolakis. (2000)[110].	**Descriptive Cross sectional study (experimental and control group).**	**Level 3b**	Sample:25 patients with TMD and 25 control subjects General description of Posture Results: patients with TMD had more postural abnormalities than healthy controls
Sonnesen(2001a). [115].	**Descriptive Case series**	**Level 4**	Sample : 96 children TMD diagnosis mixed and based on Helkimo Index Sample size by categories small (muscular , articular problems) Analysis of results with caution Results: children with Clicking and reduced mobility of the joints had marked forward head position of the head.
Visscher. (2002)[32]	**Descriptive Cross sectional study (Experimental and control groups)**	**Level 3b**	Sample: 85 non patients and 106 patients Analysis of posture per group (muscular, articular or mixed) Convenience sample Clear diagnosis (muscular, articular and mixed).However, the sample size for each group was very unequal making comparisons with caution. Results: there is not significant differences in head posture between patients and healthy subjects
Wright (2000)[27].	**Randomized controlled trial**	**Level 1b**	Sample: N = 60: 51 females/ 9 males Age: 18-60 years Diagnosis: TMD with pain minimum of 6 months, moderate severity of pain, pain in masticatory muscles Results: there was a statistically significant improvement in the modified symptom severity index, maximum pain –free opening and pressure threshold of the training group compared with self management. The authors concluded that posture training and TMD self-management together are more effective than self –management alone for patient with TMD, specifically with muscular problems.

2.4.8 CONNECTION BETWEEN CERVICAL SPINE DYSFUNCTION AND TEMPOROMANDIBULAR DISORDERS

Cervical spine dysfunction (CSD) is a collective term embracing a number of clinical problems of the musculoskeletal structures of the cervical spine. Pain is usually aggravated by moving the head or adopting certain head positions.[33] Neck pain is often the main symptom of cervical spine dysfunction related to acute (macrotrauma) or chronic (microtrauma) affecting the joints or periarticular tissues surrounding the cervical spine. Cervical spine dysfunction has been connected with TMD.[5, 6, 9, 33] De Wijer et al.[5, 6, 120, 121] concluded that symptoms of the stomatognathic system overlap in patients with TMD and CSD, and symptoms of the cervical spine overlap in the same group of patients (TMD and CSD). Also, it was found that patients with chronic TMD more often suffered from cervical spine pain than those without this disorder. [33, 122] Stiesch-Scholz et al[25] found that asymptomatic functional disorders of the cervical spine occurred more frequently in patients with internal derangement of the TMJ than in a control group. The presence of tender points in the cervical and shoulder girdle in patients with the same diagnosis was more common, especially in upper segments of the cervical spine, compared with healthy controls. These results are in agreement with those obtained by De Laat et al.[122] and Sipila et al [123]. Sipila et al.[123] found that facial pain was associated with reported pain in the neck area and clinical pain resulting from palpation in the muscles of the neck-occiput area. Significant differences in mobility of the cervical spine were not found between patients with facial pain and controls. Additionally, Ciancagliani et al [124], analyzing a randomly selected sample of 483 individuals in northern Italy, found a positive relationship between neck pain and temporomandibular disorders. This association was more marked when the TMD dysfunction was more severe. These results demonstrated that patients suffering TMD had more than double the risk (odds ratio of 2.33) of suffering neck pain than patients without TMD (odd ratio of 1). [Odds ratio provides an estimation of the number of times the risk of neck pain increases for a single subject when the TMD is present]. Individual symptoms such as facial and jaw pain were significantly associated with neck pain with odds ratio of 2.09. Based on these results, the authors suggested that an association between neck pain and TMD may be possible and a systematic clinical examination of cervical spine areas could be important in identifying possible causes of craniofacial pain. In a recent report, Pallegama et al.[125] found that patients with myogenous TMD had increased resting EMG activity of the upper trapezius muscles as well as the SCM muscles when compared with control subjects. The presence of pain over the SCM and trapezius muscles was significantly associated with masticatory muscle pain without disc displacement. Analysis of the studies referring to the relationship between head and cervical posture and TMD is presented in Table 2-9.

Table 2-9. Analysis of Studies Referring to the Connection between Cervical Spine Dysfunction and Temporomandibular Disorders.

Author and Title	Study Design	Level of Evidence	Remarks
Ciancaglini [124]	**Cross sectional study**	**Level 3b**	Sample : 483 randomly selected subjects participated in this study Results:188 (38.9%) patients had neck pain 266 (55.1%) patients had Temporomandibular Disorders It was found a significant correlation between neck pain and TMD The severity of neck pain was increased with severity of TMD
de Wijer (1996)[6].	**Descriptive Case series**	**Level 4**	Sample: 111 patients with temporomandibular disorders (TMD) complaint and 103 patients with cervical spine dysfunction (CSD) Results: no evidence to support the theoretical concept that CSD may give rise to TMD. Patients with TMD differ from patients with CSD, regarding signs and symptoms of bruxism, joint sounds, symptoms in and around the ear, and the dimension pain.
de Wijer (1996) [121].	**Descriptive Case series (no control group)**	**Level 4**	Sample: 111 patients with TMD and 103 patients with symptoms of CSD Results: patients with CSD have signs and symptoms of TMD
de Wijer, A(1996)[5].	**Descriptive Case series (no control group**	**Level 4**	Sample: 111 patients with TMD and 103 patients with CSD Results: there is a considerable overlap in the signs and symptoms of patients with TMD and patients with CSD.
Fink (2002)[9].	**Descriptive Cross sectional study**	**Level 3b**	Sample: 30 patients (with painful internal derangement) without any subjective neck problem. Control group (healthy subjects). Results: patients with internal derangement presented more silent cervical disorders in cervical spine than healthy controls.
Sipila (2002) [123].	**Descriptive Cross sectional study**	**Level 3b**	Randomization of a total 162 patients and 200 controls Sample: 40 patients with orofacial pain and 40 controls Results: facial pain is strongly associated with TMD.
Stiesch-Scholz, (2003)[25].	**Descriptive Cross sectional study**	**Level 3b**	Sample: 30 patients (with painful internal derangement) without any subjective neck problem. Control group (healthy subjects). Results: patients with internal derangement presented more often pain on pressure of the neck muscles than healthy controls
Visscher (2001). [33].	**Cross sectional study**	**Level 3b**	Sample: 147 patients with CMD complaints and 103 healthy subjects Descriptive, convenience sample Experimental and control group Results: patients with CMD often suffer from cervical spinal spine than person without it.

Pallegama (2004)[125]	**Cross sectional study**	**Level 3b**	Sample: 38 volunteers with myogenous TMD (16 males and 22 females, mean age 29 years) and a group of 41 matched healthy individuals participate in this study Results: Patients with myogenous TMD had increased resting EMG activity of the upper trapezius muscles as well as the SCM muscles when compared with control subjects Comments: no normalization of the EMG activity. Results with caution

2.5 CONCLUSION

The connections with the cervical spine, stomatognathic system, and craniofacial pains have been presented in this critical review. However, if one analyzes the information presented, from a research perspective, and based on the levels of the evidence presented by Sackett [39], it can be seen that most of the research included in this review are descriptive experiences, cross sectional studies, cohort studies and poor quality randomized control trials (RCTs), with small sample sizes, and with low power. Therefore, these studies must be interpreted with caution because of their lack of scientific rigour. However, they point out a tendency to link cervical spine, neck structures and craniofacial pain. This tendency should not be undervalued. Future investigators working on this topic should consider the findings of this review when designing future trials and attempt to overcome the limitations of the studies presented (e.g. small sample sizes, low power, no randomization, no controls). It is also recommended that researchers follow the guidelines of the CONSORT statement when designing their studies, and when reporting the methods and results sections for publication [126, 127] (see specific references for more information).

Although Sackett's method of evaluation is very easy to use, and thus studies can be organized hierarchically, the method has weaknesses as it lacks specific analysis of some important methodological points such as sample size, power, confounding variables, quality of the outcomes, and internal and the external validity, which makes the analysis of the studies limited to a specific point (study design). Also, in some cases where the studies are not treatment interventions such as neurophysiological or anatomical studies, Sackett's classification does not express the real value of the publication.

It should be also pointed out that the information obtained by databases (Medline-Pubmed, Embase, Web of Sciences, and Cochrane library) was not sufficient to cover all the published articles on this topic, therefore, manual search, or other sources for obtaining information should be mandatory in order to obtain most of the available information in the literature.

From a clinical perspective, there are probably interconnections between the cervical spine and the stomatognathic system, and consequently, a link to craniofacial pain. In addition, patients can have overlapping symptoms from different sources. The authors' advice is not to ignore the information but to realize the limitations of the studies. Investigators should be careful in the interpretation of the results, and be aware that better designed studies are required when studying the relationship between cervical spine and craniofacial pain in order to effectively prove this interaction.

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3 CHAPTER 3

THE ASSOCIATION BETWEEN NECK DISABILITY AND JAW DISABILITY

3.1 INTRODUCTION

The association between cervical spine dysfunction (CSD) and Temporomandibular Disorders (TMD) has been extensively investigated.[1-18] Numerous studies and reviews have focused their attention on the anatomical, biomechanical, neurological and physiological relationships present in the craniocervical facial region.[19-21] Most of these studies have pointed out that the presence of cervical impairments and temporomandibular disorders occurred together.[7, 8] This means that patients with TMD present more commonly with CSD than people without TMD, and individuals with CSD present more commonly TMD than people without CSD. Also, it has been reported that patients with chronic TMD suffered more often from neck pain than those without this disorder.[6, 22] Asymptomatic functional disorders of the cervical spine occurred more frequently in patients with internal derangement of the TMJ than in a control group.[23] Tender points in the cervical and shoulder girdle, especially in upper segments of the cervical spine, were more commonly present in patients with TMD than healthy subjects.[23] Furthermore, it has been found that facial pain

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was associated with neck pain resulting from palpation in the muscles of the neck-occiput area.[24]

Ciancagliani et al.,[25] found a significant relationship between neck pain and temporomandibular disorders which was more marked when the TMD dysfunction was more severe. Patients suffering TMD had more than double the odds (odds ratio: 2.33) of suffering neck pain than patients without TMD (odds ratio:1). Thus, there appears to be an association between neck pain and the presence of TMD and a systematic clinical examination of cervical spine areas could be important in identifying possible causes of craniofacial pain.[21]

Published studies investigating the relationship between cervical spine and TMD have focused on investigating the relationship between either symptoms such as neck pain, jaw pain, facial pain, and palpation pain of the cervical-shoulder girdle muscles or signs such as clicking and reduced opening of the jaw; however, to the best of our knowledge, no studies investigating the level of jaw disability and neck disability have been published. Disability and function are complex and multidimensional constructs.[26] Assessing disability is challenging, however, it has been increasingly gaining attention in painful musculoskeletal conditions since functional activities can be influenced by a several factors independently of signs and symptoms.[27] This has generated a shift focusing away from signs and symptoms evaluation toward the impact that signs and symptoms have on the function of individuals with pain.[28, 29] The International

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Classification of Functioning, Disability and Health (ICF) from the World Health Organization (WHO) has been developed to integrate the concepts of disability and functioning and to create a common language for health professionals who work with disabling conditions such as TMD and chronic pain. The ICF is a very useful framework for organizing determinants of disability based on a biopsychosocial model of functioning, disability and health. Functioning is based on body functions, body structures, activities and participation, and expresses the positive aspect of the interaction between a subject and the contextual factors of that individual. On the other hand, disability expresses the impairments (negative aspects of interactions between individual and his/her contextual factors) at the body level, activity limitations, and participation restrictions.[30] Environmental factors (i.e. physical, social and attitudinal environment) as well as the personal factors for each individual (i.e. age, gender, race, and lifestyle) determine the level of disability of individuals. Thus, the use of ICF framework as well the use of outcomes that evaluate not only body structures or functions but also evaluate the impact of these impairments on subject's activity and participation need to be addressed. This facilitates the process of evaluation and treatment implementation focusing on all aspects of disability (i.e. body structures, body function, activities and participation).[26, 27]

Jaw disability has commonly been measured using different checklists or scales.[31-35] The most commonly used checklist is from the Research

Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) called Jaw Disability Checklist (JDC).[36] This checklist has been developed by expert consensus, and has been widely used for research purposes. However, its psychometric properties have not been tested. Another scale used to evaluate the disability at the level of the jaw is a newly developed scale called "Limitations of Daily Functions in TMD Questionnaire" (LDF-TMDQ or Jaw Function Scale-JFS).[37] This JFS questionnaire as well as the RDC/TMD checklist (i.e. JDC) focuses on limitations of daily activities of patients with TMD. The JFS is brief, multidimensional and incorporates a specific evaluation for TMD patients. The JFS has been developed considering experts and clinicians' opinions, and also the RDC/TMD criteria. In addition, it has been evaluated through a rigorous statistical procedure using exploratory and confirmatory factor analysis (structural equation modeling) in order to ensure face and construct validity. This scale has been tested for convergent/divergent validity with many other scales such as the Hospital Anxiety and Depression Scale (HADS) to measure anxiety and depression, the Eysenck Personality Questionnaire Short Form (SEPQ) to measure neuroticism and extroversion, the Visual Analogue Scale (VAS) to measure pain intensity, and the dental version of the McGill pain questionnaire. However, the convergent validity of this scale with the checklist used by the RDC/TMD has not been tested, as well as the convergent validity with other measures of disability used by the RDC/TMD such as the chronic disability of TMD classification.[37]

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Neck disability has been commonly evaluated through many scales [29], however, the most used and validated scale to evaluate neck disability has been the Neck Disability Index (NDI).[29, 38, 39] This scale has been used in many settings and for different conditions to evaluate the impact of neck pain. However, no information regarding the use of neck disability in a population of subjects with TMD was found. As mentioned by Pietrobon et al., [29] information regarding the NDI in other populations could increase the validity evidence of the NDI in different populations.

This study was designed to increase the body of knowledge regarding the association between jaw disability and neck disability as measures of the impact of pain on function as well as activities of daily living in patients with TMD. In addition, this study focused on increasing the validity and reliability evidence of the JFS and NDI in the area of temporomandibular disorders.

3.2 OBJECTIVES

1. The main objective of this study was to determine whether there was a relationship between neck disability measured using the Neck Disability Index (NDI) and jaw disability measured through the Jaw Function Scale (JFS). The secondary objectives of this study were:

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2. To determine the relationship between the level of chronic disability of TMD based on the RDC/TMD (Chronic Pain Grade Disability Questionnaire) and the neck disability measured through the NDI.

3. To determine the convergent validity of the Jaw Function Scale (JFS) with the Jaw Disability Checklist (JDC) used by the RDC/TMD.

4. To determine the relationship between level of chronic disability of TMD based on the RDC/TMD (Chronic Pain Grade Disability Questionnaire), pain intensity, neck disability and the jaw disability measured through the Jaw Function Scale (JFS) and the Jaw Disability Checklist (JDC) used by the RDC/TMD.

5. To determine test-retest reliability of the JFS and NDI in the analyzed population.

3.3 RESEARCH HYPOTHESES

The following hypotheses were investigated in this study:

1. There will be a strong relationship between neck disability measured using the Neck Disability Index (NDI) and jaw disability measured using the Jaw Function Scale (JFS).

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2. There will be a strong relationship between the level of chronic disability of TMD based on the RDC/TMD (Chronic Pain Grade Disability Questionnaire) and the neck disability measured using the NDI.

3. There will be convergent validity between the Jaw Function Scale (JFS) and the Jaw Disability Checklist (JDC) used in the RDC/TMD.

4. There will be a strong relationship between the level of chronic disability of TMD based on the RDC/TMD (Chronic Pain Grade Disability Questionnaire), pain intensity, neck disability and the jaw disability measured using the Jaw Function Scale (JFS) and the Jaw Disability Checklist (JDC) used in the RDC/TMD.

5. There will be a good test–retest reliability of the JFS and NDI in the analyzed population.

3.4 METHODS

3.4.1 SUBJECTS

A convenience sample of subjects who attended the TMD/Orofacial Pain Clinic at the School of Dentistry, Faculty of Medicine and Dentistry, University of Alberta and healthy students and staff at the University of Alberta was recruited for this study using advertising in different faculties and surrounding areas of the University of Alberta (Appendix 1). The sample size for this study was calculated according the guidelines established by Cohen regarding

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correlational studies (first objective).[40] Considering $\alpha=0.05$, an effect size of 0.4 (r) and power of 0.80, a total minimal number of 59 subjects was required.

The inclusion/exclusion criteria for healthy as well as subjects with TMD were as follows:

3.4.1.1 Healthy Subjects

3.4.1.1.1 Inclusion Criteria:

1. Healthy females between the ages of 18 and 50 years to decrease the chance of degeneration factors and growth factors that could affect the temporomandibular joint (TMJ), or the cervical spine, and might affect the outcomes [41] .

3.4.1.1.2 Exclusion criteria:

1. History of chronic pain or clinical pathology or previous surgery related to the masticatory system or cervical spine.
2. History of TMD symptoms for at least one year before commencing the study.
3. Abnormal range of movement (ROM) of the TMJ or cervical spine.[42]
4. Postural abnormalities of the craniocervical system and spine such as scoliosis and hyperkyphosis evaluated by a physical therapist.[43]

5. Neurological problems (central or peripheral such as radicular pain, stroke, or any neuropathy that could alter balance) that could interfere with the experimental procedure and the outcomes.
6. Any acute or chronic injury or systemic disease such as acute pain, diabetes mellitus, or asthma, or neurological disease which could interfere with the outcome
7. Taking medication specifically designed to affect the musculoskeletal system such as anti-inflammatory or pain relieving drugs, muscle relaxants or arthritic medications.
8. Unreliable subjects (e.g. mentally impaired).

3.4.1.2 Patients with Temporomandibular Disorders (TMD)

3.4.1.2.1 Inclusion Criteria for all Patients with TMD

1) Females 18-50 years of age
2) Pain in the masticatory muscles/temporomandibular joint for at least 3 months not attributable to recent acute trauma, active inflammatory cause, or previous infection.
3) A moderate or severe baseline pain score of 30 mm or greater using a 100 mm VAS.[44]

3.4.1.2.1.1 Additional Inclusion Criteria for Patients with Myogenous TMD

1) Be diagnosed as having myogenous TMD based on the classification Ia and Ib of Dworkin and LeResche[36] "patients must present pain or ache

in their masticatory muscles, face, and preauricular area or inside the ear at rest or during function." (p. 328). This diagnosis was based on clinical assessment following the guidelines of the diagnostic research criteria for TMD.[36] If subjects had pain upon palpation in at least three of the 12 following points proposed by Fricton et al.: [45-47] Temporalis (anterior, medial and posterior belly) and Masseter (deep belly, and the inferior and anterior portion of the superficial belly) bilaterally and did not complain of painful clicking, crepitation or pain in the TMJ at rest or during function,[48] and during the compression and retrusion tests were diagnosed as having myogenous TMD.[49]

3.4.1.2.1.2 Additional Inclusion Criteria for Patients with Mixed TMD

1) Be diagnosed as having mixed TMD. That is, patients could complain of muscular symptomatology (same as above) in addition to articular symptomatology such as painful clicking, crepitation or pain in the TMJ at rest or during function,[48] and during compression and retrusion tests test.[49]

3.4.1.2.2 Exclusion Criteria:

1. Dental or periodontal disease, oral pathology lesions, oral infection, or neuropathic facial pain as evaluated by a dentist from the TMD/Orofacial pain Clinic from the Faculty of Medicine and Dentistry at the University of Alberta

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2. Surgical history to the craniomandibular system, and evidence of neurological or bone disease, systemic disease, or cancer.
3. Unreliable subjects (e.g. mentally impaired).

3.4.2 CLINICAL ASSESSMENT

Subjects underwent a clinical examination by a physical therapist with 14 years of experience in musculoskeletal rehabilitation and treatment of temporomandibular disorders (principal investigator) to determine if they met the inclusion criteria or were excluded by the exclusion criteria for this study. Clinical examination followed the guidelines of the diagnostic research criteria for TMD.[36] Briefly, subjects were examined for pain in masticatory muscles, TMJ joint, and also TMJ range of motion (Appendices 2 and 3).

If the physical therapist felt the subject did not meet the inclusion criteria, the subject was excluded of the study. Subjects were asked to read an information letter (appendix 4) and sign an informed consent in accordance with the University of Alberta‘s policies on research using human subjects (appendix 5).

3.4.3 PROCEDURES

3.4.3.1 General Considerations

Demographic data were collected on all subjects who satisfied the inclusion criteria including age, weight, and height. In addition, all subjects were asked to report specific characteristics regarding their jaw problem (i.e. onset,

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duration of symptoms, treatments received). All subjects were also asked to report their intensity of pain in the jaw (VAS), and also complete the Neck Disability Index (NDI) (appendix 6), the Jaw Function Scale (LDF-TMDQ/JFS) (appendix 7), and a history questionnaire for jaw pain used by the RDC/TMD (appendix 8). In addition, the subjects were asked to complete the Chronic Pain Grade Disability Questionnaire for TMD used by the RDC/TMD to evaluate the level of chronic disability due to TMD (appendix 9) and the jaw Disability Checklist (JDC) used by the RDC/TMD (appendix 10).

3.4.3.2 Pain Intensity Report (Visual Analogue Scale-VAS)

All patients with TMD were asked to report the average pain intensity experienced in the last week on a VAS. The validity and reliability of these methods for determining pain intensity, has been reported and confirmed in the literature.[44, 50-53] The VAS is a linear scale 100 mm in length, has a rectangular shape of 10 cm long with both ends labeled with the two extremes boundaries of pain sensation: “no pain”, at one end and “worst pain imaginable” at the other end. Subjects were to mark the scale to select their pain rating and then this was transformed into a numerical (mm) score**.** Based on the study performed by Collins et al.,[44] moderate pain was considered to be over 30 mm, and severe pain over 54 mm, on the pain intensity scale.

3.4.3.3 Neck Disability Report (Neck Disability Index-NDI)

The Neck Disability Index is a questionnaire that measures how much neck pain affects activities of daily living such as personal care, lifting, reading, headaches, concentration, work, driving, and sleeping. The NDI is a relatively short questionnaire that can be easily administered. It is comprised of 10 items. These 10 items are each scored out of 5 for a maximum total score of 50 (appendix 6). The Neck Disability Index has been extensively used and investigated in the literature. It is by far the most commonly used questionnaire for evaluating neck disability in research and clinical settings (around 300 hundreds publications). In addition, the NDI has been translated into 22 languages and its use has been recommended in many clinical guidelines. A recent systematic review [39] related to the NDI found that the NDI is a strong, validated instrument for assessing self-rated disability in patients with neck pain. Its internal consistency ranged between 0.74-0.93 (excellent consistency) and its reliability between 0.90-0.97. Also the responsiveness of the NDI has been established (3-5 points of clinically important difference, depending on the investigated population).[39] The NDI has been found to have convergent validity with McGill pain questionnaire, and has been used as gold standard to validate other neck disability tools.[29, 39, 54, 55] Furthermore the NDI has a prognostic value as a measure of "symptom/disability" in clinical trials (predictive validity).[39]

For the purpose of this study, the total score of the questionnaire summing the patient's answers was used for statistical purposes. The level of neck disability for the NDI has been determined as follows: 0-4 points: "no disability", 5-14 points: "mild disability", 15-24 points: "moderate disability", 25-34 points: "severe disability", and > 35 points: "complete disability".[39]

3.4.3.4 Jaw Function/Disability Report (Jaw Function Scale-JFS)

Jaw function/disability was measured using a self-reported questionnaire called "Limitations of Daily Functions in TMD Questionnaire" (LDF-TMDQ/JFS) developed by Sugisaki et al.[37] This questionnaire focuses on limitations of daily activities of patients with TMD. It is brief, multidimensional and incorporates specific evaluations for TMD patients (appendix 7). It was developed based on an analytical process, considering a set of pain-related limitations based on clinician and patient experiences as well as the RDC/TMD criteria. The development of the questionnaire was also based on a rigorous statistical procedure through the use of exploratory and confirmatory factor analysis (i.e. structural equation modeling) in order to ensure face and construct validity. The questionnaire consists of 10 items and 3 factors. These factors were extracted by exploratory factor analysis. The first factor is called "limitation in executing a certain task" and is composed of five items dealing with daily physical and psychosocial activities. The second factor is called "limitation of mouth opening" which is composed of three items, and the third factor,

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"limitation of sleeping" is composed of two items. The internal consistency of this questionnaire (calculated by Cronbach α) was 0.78 for the 10 items, 0.72 for "limitation in executing a certain task", 0.73 for "limitation of mouth opening", and 0.77 for "limitation of sleeping", indicating a good internal consistency. The LDF-TMDQ was tested for convergent validity with the dental version of the McGill Pain Questionnaire. They had correlations ranged between 0.49-0.54. Discriminant validity was established measuring the correlations between the factors of this scale with scales for measuring anxiety and depression [the Hospital Anxiety and Depression Scale (HADS)], and measure neuroticism and extroversion [Eysenck Personality Questionnaire Short form (SEPQ)]. All of the factors of the JFS had low correlations with these scales indicating that these factors were theoretically unrelated with the clinical constructs. [37]

Each item was evaluated using a five-point numeric rating scale graded from 1 (no problem) to 5 (extremely difficult). The patients were asked to choose one of the five ratings on the scale in response to the following question: "how much does your present jaw problem prevent or limit your daily functions?" The total score of the questionnaire summing the patient's answers was used for statistical purposes. The maximum total score was 50 points (Appendix 7).

Subjects were asked to answer the NDI and JFS at a second opportunity in order to know the status of their condition. This information was used also to evaluate test-retest reliability of these scales. Subjects were re-sent the questionnaires and were asked if they have changed their status regarding symptoms, treatments and condition between evaluations. Subjects were excluded of the reliability analysis if they reported a substantial change in their condition (i.e. receiving a new treatment, new medication). The mean average between assessments (time 1 and time2) was 12.64 months.

3.4.3.5 Level of Chronic Disability of TMD based on the RDC/TMD (Chronic Pain Grade Disability Questionnaire) and Jaw Disability Checklist (JDC) from the RDC/TMD

The level of chronic disability of TMD (Chronic Pain Grade Disability questionnaire) (appendix 9) was used in this study as well as the JDC from the RDC/TMD (appendix 10). The instruments of the RDC/TMD for examining, diagnosing, and classifying the most common subtypes of TMD have been considered a guide that provides clinical researchers with a standardized system with clear face and criterion validity.[56] These instruments have been recommended as a model system for the standardization of an investigation in diagnosis and classification of any chronic pain condition (appendix 8).

The level of chronic disability of TMD used by the RDC/TMD classifies each subject at 5 different levels of disability according to: the level of pain intensity, the number of days of disability, and the interference of pain with activities of daily living (appendix 9). The 5 levels of chronic disability classification used by the RDC/TMD are displayed in Table 3-1:

Table 3-1. Chronic Pain Grade Classification (CPGDC)

Disability Grade	
Grade 0: No Disability	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 > 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

The JDC used by the RDC/TMD is a self-reported questionnaire consisting on 12 items focusing also on limitations of daily activities of patients with TMD (appendix 10). The subject had to answer to the 12 items with “yes/no” responses depending if the analyzed item limited the subject’s daily activities. The total score of the questionnaire summing the “yes” answers was used for statistical purposes.

3.5 ANALYSIS

The data were explored for normality using histograms, Q-Q plots, and the Kolmogorov-Smirnov test. A Spearman rho test was used to analyze the relationship between neck disability and jaw disability (objective 1). Multiple regression analysis was used to determine the association between the level of chronic disability of TMD based on the RDC/TMD (Chronic Pain Grade

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Disability Questionnaire) and the neck disability (objective 2). In order to analyze the convergent validity between the JFS and the Jaw Disability Checklist (JDC) used by the RDC/TMD; a Spearman rho test was also used (objective 3). In order to analyze the relationships between the level of Chronic Pain Grade Disability classification due to TMD used by the RDC/TMD, pain intensity, neck disability and the jaw disability measured through the Jaw Function Scale (JFS) and the JDC used by the RDC/TMD, a Spearman rho test was also used (objective 4). The test-retest reliability of the JFS and NDI was evaluated through an intraclass correlation coefficient (ICC) derived from a mixed model two way analysis of variance in which assessment was the fixed factor and patients were modeled as random.[57] The criteria proposed by McDowell,[58] was used to interpret the ICC values. Values above 0.75 indicated excellent agreement, 0.6-0.74 showed good agreement, 0.4 to 0.59 indicated fair to moderate agreement, and below 0.4 was poor agreement. Standard error of the measurements for test-retest reliability was calculated according to the guidelines established by Weir [59] using the mean square value obtained from the ANOVA table.

The correlation was considered important when the correlation coefficient value was higher than 0.70. The reference values to make this decision were based on values reported by Munro[60] (Table 3-2).

Table 3-2 Reference Values for Correlation Coefficients According to Munro [60]
• 0.00-0.25: little correlation
• 0.26-0.49: Low correlation
• 0.50-0.69: Moderate Correlation
• 0.70-0.89: High correlation
• 0.90-1.00: very high Correlation

The SPSS program version 17 and STATA program version 10 were used to perform the analysis.

All data have been reported in means ± standard deviation (SD), unless otherwise stated.

3.6 RESULTS

3.6.1 SUBJECTS

A total number of 172 subjects were assessed for inclusion in this study. A total of 18 subjects were excluded. The main reasons for exclusion were: being not totally healthy (9 subjects), being older than 50 years old (2 subjects), having a neurological disease (1 subject), having cancer (1 subject), or the pain score was lower than 30 mm in the visual analogue scale (5 subjects).

One hundred and fifty four participants (154) provided data for this study. From these 154 subjects, 50 subjects were healthy, 56 subjects had myogenous temporomandibular disorders (TMD) and 48 subjects had mixed TMD.

3.6.2 *Sample Characteristics*

The general demographics for each group are shown in Table 3-3.

Table 3-3. Descriptive Statistics of Height, Weight and Age for all Subjects (i.e. Myogenous TMD, Mixed TMD and Healthy Subjects)

	Group	Mean	Std. Deviation	N
Height (cm)	Myogenous TMD	164.86	5.13	56
	Healthy	165.26	6.65	50
	Mixed TMD	166.08	6.00	48
Weight (Kg)	Myogenous TMD	64.59†*	10.98	56
	Healthy	64.02	12.35	50
	Mixed TMD	71.53*	16.14	48
Age (years)	Myogenous TMD	31.14	8.94	56
	Healthy	28.28	7.26	50
	Mixed TMD	31.48	8.24	48
Duration of complaint (years)	Myogenous TMD	6.51*	6.33	56
	Healthy	0.00	0.00	50
	Mixed TMD	8.22*	6.43	48
Pain Intensity (0-100 mm)	Myogenous TMD	46.76*	16.23	56
	Healthy	0.00	0.00	50
	Mixed TMD	49.25*	16.09	48
Jaw Function Scale (10-50 points)	Myogenous TMD	18.95†*	6.39	56
	Healthy	10.12	0.39	50
	Mixed TMD	22.81*	7.20	48
Neck Disability Index (0-50 points)	Myogenous TMD	10.87*	5.75	56
	Healthy	1.78	1.65	50
	Mixed TMD	12.81*	6.94	48

*** Significantly different when compared with healthy subjects at α=0.05**
† Significantly different when compared with subjects with mixed TMD at α=0.05

Since the answer to questionnaires was voluntary, only 134 subjects agree to complete the RDC/TMD scales questionnaire and did not experience a substantial change in their condition (i.e. TMD) in the second opportunity. The main reason for not completing the questionnaire was that the questionnaire was too long and required much time to fill it. In addition, these 134 subjects agreed to complete the NDI and JFS the second time. There were 44 healthy subjects, 45 subjects with myogenous TMD and 44 subjects with mixed TMD. Thus, the sample size obtained from people answering the questionnaires for each group was equivalent. The demographics of the people answering the questionnaire by group did not show statistically significant differences when compared with the full sample.

There were no significant differences in the sample in age and height. However, weight was significantly different between healthy subjects and subjects with mixed TMD (mean difference 7.5 kg [95%CI 2.241, 12.793] p=0.006) and between subjects with mixed TMD and myogenous TMD (mean difference 6.9 kg [95%CI 1.813, 12.084] p=0.008). No weight differences were found between healthy subjects and subjects with myogenous TMD.

Subjects with TMD (mixed and myogenous) were significantly different from healthy subjects in all symptom characteristics (i.e. pain intensity, time of complaint, Neck Disability Index Score and Jaw Disability Score). Subjects with mixed TMD were similar to subjects with myogenous TMD in most of the general characteristics such as years of complaint and pain intensity (p>0.05). The average pain intensity on VAS scale for patients with myogenous TMD was 47.64 mm and 49.25 mm for subjects with mixed TMD. Regarding duration of complaint, most of the patients had a long history of pain with an average of 8.2 years of pain for subjects with mixed TMD and an average of 6.5 years for subjects with myogenous TMD.

Related to the level of disability of the subjects with TMD, neither group presented with a high level of disability either in the neck or in the jaw. The maximum score for the Neck Disability Index is 50, and the subjects having mixed TMD only have an average of 12.81 points and the subjects with myogenous TMD had 10.87 points. Both values are considered only mild neck disability.(29, 31) Related to the Jaw Function Scale, the maximum score is 50 points and the average obtained by the subjects with mixed TMD was 21.08 for and only 17.50 for the subjects with myogenous TMD. Based on these two scales, the severity for both types of disability in this sample of patients was not severe.

The Jaw Function Scale Score was statistically significantly higher for subjects with mixed TMD compared to myogenous TMD subjects (Mean difference 3.6 points, p=0.001 [95%CI 1.566, 5.6]). Neck Disability Scores were not statistically significantly different between subjects with mixed TMD when compared with myogneous TMD, however, subjects with mixed TMD presented with a higher disability score than the subjects with myogenous TMD.

The frequency of Chronic Pain Grade Disability classification by group is presented in Table 3-4.

Table 3-4. Group and Chronic Pain Grade Disability Classification Cross Tabulation

Count: number of subjects

		Chronic pain Grade classification					Total
		0	**I**	**II**	**III**	**IV**	
Group	**Myogenous TMD**	**0**	**19**	**1**	**24**	**1**	45
	Healthy	**45**	**0**	**0**	**0**	**0**	45
	Mixed TMD	**0**	**12**	**3**	**22**	**7**	44
Total of subjects		**45**	**31**	**4**	**47**	**8**	134
%		33.58	23.13	2.9	35.07	5.9	100

Analyzing the percentage of Chronic Pain Grade Disability in this population, it was found that 33.58% had no disability, 23.13% had grade I (low level disability), 2.9 had grade II (high intensity disability), 35.07 had grade III (moderately limiting disability), and only 5.9% had level 4 or severely limiting disability.

3.6.3 Relationship between NDI and JFS

It was found that the correlation between jaw disability and neck disability was significantly high ($r=0.82$, $R^2=0.67$ $p<0.05$). Subjects who had no or low levels of jaw disability (evaluated through the JFS), also presented with no or low levels of neck disability (evaluated through the NDI) in this sample. People who had more severe jaw disability had higher levels of neck disability. (Table 3-5, Figure 3-1). The coefficient of variation determined that almost 67% of the variance of the score on the Jaw Function Scale was explained by the Neck Disability Index. This means that the scores of jaw disability depend to a great extent on the levels of neck disability.

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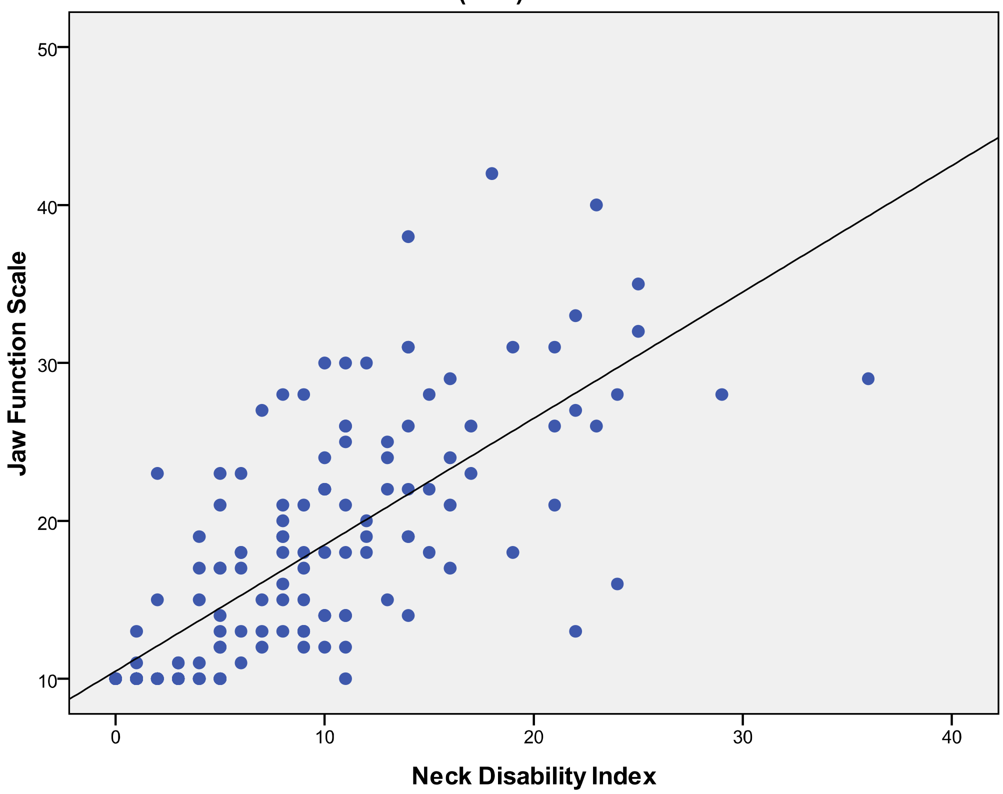
Table 3-5. Correlation Between Neck Disability Index and Jaw Function Scale

			Neck Disability Index
Spearman's rho	**Jaw Function Scale**	**Correlation Coefficient**	**0.82****
		Sig. (1-tailed)	**0.0**
		N	154

** Correlation is significant at the 0.01 level

Figure 3-1. Correlation between Neck Disability (NDI) and Jaw Function Scale (JFS)



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3.6.4 RELATIONSHIP BETWEEN THE LEVEL OF CHRONIC DISABILITY OF TMD USED BY THE RDC/TMD AND THE NECK DISABILITY MEASURED THROUGH THE NDI

A multiple regression analysis used to test the association between level of chronic disability of TMD (as measured by the RDC/TMD) and the neck disability (measured by the NDI), demonstrated that there was a significant association between these variables (F 4, 130=41.44 $p<0.005$, $R^2=0.56$). The R^2 ("which is a measure of how well the independent variables account for the outcome"[61][p.119]) indicates that the level of chronic disability of TMD significantly explains the variance of neck disability. The variance explained by this model was about 56% of the total variance in neck disability. According to the results obtained in this study, when analyzing the levels of disability, one can say that a person who has a level I Chronic Pain Grade Disability due to TMD will increase the NDI by 7.03 points compared with a person who does not have disability (Chronic Pain Grade Disability= 0). A person who has a Chronic Pain Grade Disability due to TMD grade IV will increase 19.32 points on the Neck Disability Index when compared with a person without TMD disability (Table 3-6).

Table 3-6. Multiple Regression Analysis Relationship between the Level of Chronic Pain Grade Disability due to TMD and the Neck Disability Index.

Neck Disability |	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
CPD Grade I |	7.03	1.16	6.08	0.000	4.74	9.32
CPD Grade II |	6.20	2.57	2.41	0.017	1.11	11.28
CPD Grade III |	10.51	1.02	10.29	0.000	8.49	12.54
CPD Grade IV |	19.32	1.89	10.24	0.000	15.59	23.05
constant |	1.80	0.73	2.48	0.014	0.37	3.24

CPD= Chronic Pain Disability
NDI: neck Disability Index
RDC/TMD: Research Diagnostic Criteria
***significant at α=0.05**

3.6.5 Convergent Validity between RDC/TMD Jaw Disability Checklist (JDC) and JFS

When evaluating the convergent validity between the JFS and the JDC, the correlation was high, demonstrating a high convergent validity between these two measurements (Table 3-7).

Table 3-7. Convergent Validity between Jaw Function Scale (JFS) and the Jaw Disability Checklist.

			RDC/TMD Jaw Disability Checklist
Spearman's rho	**Jaw Function Scale**	**Correlation Coefficient**	**0.84****
		Sig. (1-tailed)	**0.00**
		N	134

** Correlation is significant at the 0.01 level

3.6.6 The Convergent Validity of JFS, JDC used by the RDC/TMD, Pain Intensity (VAS), and the level of Chronic Pain Disability of TMD based on the RDC/TMD (Chronic Pain Grade Disability Questionnaire)

All correlations were found to be significant and high. Pain was highly correlated with jaw disability measured by both scales - the JFS and the RDC/TMD checklist (r= 0.80 and 0.77 respectively). However, pain correlated higher with the JFS (r=0.80) than with the RDC/TMD jaw checklist. The JFS correlated highly with Neck Disability Index (NDI), Chronic Pain Grade Disability Classification (CPGC) for TMD, and pain intensity (r= 0.82, 0.82, and 0.80 respectively). Chronic Pain Grade Disability Classification (CPGC) had a high correlation with all of the measurements as well as the jaw disability RDC/TMD checklist. Nevertheless, the jaw disability RDC/TMD checklist had lower correlations with all scales when compared with the JFS (Table 3-8)

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Table 3-8. Correlation Matrix among Pain Intensity, Jaw Function Scale, Chronic Pain Grade Disability, Neck Disability Index, and Jaw Disability Checklist.

Scale	Pain Intensity (VAS)	Jaw Function Scale (JFS)	Chronic pain Grade Classification	Neck Disability Index	Jaw Disability RDC/TMD Checklist (JDC)
Pain Intensity (VAS)	**1.000**	**0.800****	**0.799****	**0.767****	0.770**
Jaw Function Scale (JFS)	**0.800****	**1.000**	**0.824****	**0.817****	0.842**
Chronic Pain Grade Disability classification	**0.799****	**0.824****	**1.000**	**0.771****	0.781**
Neck Disability Index	**0.767****	**0.817****	**0.771****	**1.000**	0.759**
RDC/TMD Jaw disability Checklist (JDC)	0.770**	0.842**	0.781**	0.759**	1.000

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

3.6.7 TEST-RETEST RELIABILITY OF THE JFS

The test-retest reliability of the JFS was ICC= 0.82 [95% CI 0.73-0.88] (Table 3-9). This ICC was considered excellent. [58] The standard error of the measurement was 2.53 points (SEM JFS=2.53 points) (Table 3-9). The mean average between assessments (time 1 and time 2) was 12.64 months.

Table 3-9. Intraclass Correlation Coefficient for Jaw Function Scale at Time 1 and Time 2.

	Intraclass Correlation	95% Confidence Interval	
		Lower Boundary	Upper Boundary
Single Measures	0.818	0.728	0.881

3.6.8 *TEST-RETEST RELIABILITY OF THE NDI*

The test-retest reliability of the NDI was ICC= 0.74 [95% CI 0.73-0.88] (Table 3-10). This ICC was considered good. [58] The standard error of the measurement was 2.99 points (SEM NDI=2.99 points) (Table 3-10). The mean average between assessments (time 1 and time 2) was 12.64 months.

Table 3-10. Intraclass Correlation Coefficient for Neck Disability Index at Time 1 and Time.

	Intraclass Correlation	95% Confidence Interval	
		Lower Boundary	Upper Boundary
Single Measures	0.736	0.606	0.828

3.7 DISCUSSION

The main result of this study indicates that there is a strong association between neck disability measured using the Neck Disability Index and jaw disability measured through the Jaw Function Scale (JFS). Thus, the results support the main hypothesis of this study (first hypothesis). This means that people who suffer from temporomandibular disorders which have a high impact on their lives, also have a high disability in the neck region. This is an important finding, since until now, only a relationship based on signs and symptoms between neck and jaw has been established.[62-64] However, this kind of relationship only considers the presence or absence of signs and symptoms and does not take into consideration the disability caused by them. The real impact that signs and symptoms have on jaw functioning can be quite different among individuals. Slight or moderate signs can be perceived as severe limiting factors for some subjects. On the other hand, signs that are regarded as not serious could potentially cause a great deal of disability for other subjects. Thus disability evaluation can truly evaluate the compromised state of the individual when faced with a condition.

In addition, it was found that the level of chronic disability of TMD determined by the RDC/TMD had a strong relationship with neck disability accepting our second hypothesis. This means that people with a high degree of TMD disability had a high degree of neck disability. These results are in agreement with the results described above. Having a TMD disability of IV, which means that a high level of TMD disability is present, also showed an increase of about 19.32 points on the Neck Disability Index when compared with no TMD disability. These results show a strong association between disability caused by TMD and neck disability. This implies that not only signs and symptoms between the neck and jaw regions could be shared (i.e. impairment of body structures and body functions), but also the level of disability or the impact that these signs and symptoms have on the subjects lives (i.e. impairment in activities and participation). This fact has implications for evaluation and treatment decisions. It is important for clinicians to know the level of disability of their patients to determine the actions needed to reduce the disability. According to a recent review,[26] disability, based on the framework of the ICF, goes beyond the consideration of mere disease. This means that health professionals need to look

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beyond the diagnostic signs and symptoms in order to treat and reduce disability. Thus, the results of the present study highlight the fact that patients with TMD present with disability at the level of the jaw and neck and clinicians need to be aware of this when deciding treatment strategies to deal with levels of disability of patients with TMD.

As pointed out by a recent review,[21] many connections between the cervical spine and the craniofacial region exist and many sources of pain can be linked between the two areas. Facet joints, discs as well as muscles of the cervical spine could cause pain in the craniofacial region. Thus, all of these structures could contribute to generate this interplay between neck and jaw disability. However, it is still unknown which of these structures play a predominant role in generating the link and causing the disability observed in patients with TMD. In addition disability and function are complex constructs that depend not only on a series of physical signs and symptoms (i.e. body functions and body structures). The etiology of disability is multifactorial. Scott et al., [65] in a multi-international study, found that physical and mental conditions are both important determinants of disability. However, subjects with both mental and physical disorders were more likely to have severe disability when compared to people without both conditions. It has also been found that other factors such as stress, [66] a person's coping status, self-efficacy, [67] patient's beliefs, lifestyle, and environmental factors are related to disability.[30] These results point out that all of these factors- physical, mental and psychosocial need to be addressed when implementing a treatment. In this way, disability can be managed and adequately reduced.[65]

Other findings from the present study were that the JDC used by the RDC/TMD had good convergent validity with the JFS (confirming our 3rd hypothesis). This means that both scales are designed to measure the same construct (i.e. jaw disability). Regarding the correlations among the jaw disability scales and other indices of disability such as pain intensity and Chronic Pain Grade Classification (CPGC), it was found the JFS had higher correlations with these indices than the JDC used in the RDC/TMD. This could indicate that the JFS could tap a more global construct of jaw disability than the JDC. The original study of Sugisaki et al.,[37] established the convergent validity between the JFS and the VAS and the dental version of the McGill Pain Questionnaire. They found small to moderate correlations between the JFS and these two measurements (0.28-0.49 for McGill Pain Questionnaire and 0.17 to 0.31 for VAS). However, the present study found high correlations between the JFS and VAS (r=0.8). In addition, Ohrbach et al.[32] tested the convergent validity of the JDC used by the RDC/TMD against the level of pain intensity of the RDC/TMD. They found a moderate correlation between the two measurements (r=0.47) which is smaller than the level of correlation found in the present study. These differences found among studies could be explained by the different populations and settings used in each study. In addition, the differences in results could be due to the different tools used to determine jaw disability as well as pain intensity in the previous studies. Thus, the constructs being measured could have differed in the analyzed studies.

The JDC used by the RDC/TMD had only face validity (i.e. its content seems to be measuring what it is supposed to measure [68]), content validity (i.e. items represent reflect all the significant aspects of the construct being measure[68]) and to a certain extent, construct validity (refers to the scale's behaviour in relation to other related assessment tools [68]).[32] Higher levels of validity have not been reported. On the contrary, the JFS, when validated, demonstrated face, content and higher levels of validity (e.g. convergent, divergent, construct, and discriminant validity). However, this scale has not been used extensively in the literature to evaluate jaw disability. According to Turp et al.,[31] in a recent systematic review regarding oral-health related quality of life measurements, the JFS is a newly and well developed tool to measure pain-related limitation of daily function for patients with TMD. However, the use of the JFS needs to be assessed in different populations and more validity evidence needs to be added to make it more known in the orofacial pain field. Thus, this study contributes to increasing the validity evidence for both of these scales and to highlight their virtues and limitations when evaluating jaw disability in patients with TMD.

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It has been found that an important group of patients with TMD suffer from long standing persistent pain that could potentially affect their level of activity and participation in daily activities.[69] Thus, valid and reliable measures that enable one to detect how TMD affects function and contributes to disability are an important matter. No information was found that evaluates the test-retest reliability of the JFS scale. According to the results of this present study, the test-retest reliability of the JFS (ICC=0.82 SEM=2.53 points) was excellent even though the time interval between time 1 and 2 was over a year (an average of 12.64 months between assessments) accepting our 5th hypothesis. This means that the results obtained from this scale could be stable over time in a group of people with unchanging conditions such as the one investigated in this study (i.e. chronic jaw pain). Although test-retest reliability could have been influenced by the long period of testing and other factors such as change of pathological condition, change in subject's status, or other events happening in this period of time, because of the chronic nature of the condition evaluated in this study, these mentioned factors may have not played a significant role in the test-retest reliability of this scale. This result is important for clinical practice because it is essential to have reliable measures to evaluate outcomes of interest. In addition, outcomes measures need to be responsive (i.e. the ability of an instrument to detect small but important clinical changes).[70] More research looking at other psychometric properties of the JFS such as responsiveness, and to see if one can detect change after a determined treatment, are needed.

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The Neck Disability Index has been used to determine neck disability in many different populations such as patients with neck pain, radicular pain, and whiplash associated disorders (WAD);[39] To the best of our knowledge, this is the first time that this scale has been tested in patients with TMD. The high degree of correlation with the tools used to measure jaw disability such as level of chronic disability of TMD used by the RDC/TMD, the jaw pain intensity measured through the VAS, the JFS, and the Jaw Disability Checklist from the RDC/TMD indicate that jaw pain and disability are closely related to neck disability. These results are in agreement with many studies investigating the association of Cervical Spine Dysfunction (CSD) and craniofacial pain.[6-8, 22] Clinicians need to be aware of this relationship when assessing and treating patients either with TMD or neck pain related disorders.

An additional finding of this study was the test-retest reliability of the NDI in this population. The NDI test-reliability was found to be good. These results are in agreement with most of the studies evaluating the NDI test-retest reliability. As reported by a recent systematic review regarding the psychometric properties of the NDI,[39] the test- retest reliability ranged from 0.90-0.93 with an interval between time 1 and time 2 of about 1 day to 3 months. The test-retest ICC value for the present study was lower (ICC=0.74, SEM=2.99) than that reported previously. However, the time interval between time 1 and time 2 for the present study was much longer) than those previously reported. The present study

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contributes to increasing the validity evidence of the NDI in a TMD population and the Neck Disability Index could be used as a tool to determine neck disability in these patients. However, according to Chan Ci En et al.,[54] the NDI could be complemented with Patient-Specific Questionnaires (PSQ) which can capture broader aspects of disability.

3.8 CONCLUSION

Based on the results of this study, the relationship between neck disability and jaw disability was present. This means that in this population of subjects with mixed TMD, myogenous TMD and healthy subjects, people having more disability in the neck have more jaw disability and vice versa. In addition, these results pointed out that a subject with TMD disability of grade IV, measured though the level of chronic disability of TMD, which means that a high level of TMD disability exists, increase by about 19.32 points on the Neck Disability Index when compared with a person without TMD disability. There were high correlations between JFS, Jaw Disability RDC/TMD Checklist, pain intensity and level of chronic disability of TMD. Good to excellent test-retest reliability was found for JFS and NDI. This study contributes to increase the validity evidence of the JFS and NDI in population of patients with TMD.

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4 CHAPTER 4

THE ASSOCIATION BETWEEN HEAD AND CERVICAL POSTURE WITH INTRA-ARTICULAR AND MUSCULAR TEMPOROMANDIBULAR DISORDERS: A SYSTEMATIC REVIEW

4.1 INTRODUCTION

Temporomandibular Disorders (TMD), also referred to as Craniomandibular Disorders (CMD), consist of a group of pathologies that affect the masticatory muscles, the temporomandibular joints (TMJ) and/or related structures.[1, 2] Although universal consensus has not been reached, TMD is considered a musculoskeletal disorder of the masticatory system which is usually manifested by one or more of the following signs and symptoms: pain, joint sounds, limitation in jaw movement, muscle tenderness, and joint tenderness.[3] *O*ther symptoms affecting the head and neck region such as headache, ear related symptoms and cervical spine disorders are also sometimes associated with TMD.[4, 5]

Epidemiological studies report that 50% to 75% of the general population exhibits at least one sign of TMD, whereas about 25% of the population have symptoms of TMD[4, 6]. While TMD commonly occurs, it is estimated that only one fifth of symptomatic individuals will actually seek evaluation and care [7].

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Head posture has been studied for many years regarding its association with occlusion[8-11], as a factor in the development and function of the dentofacial structures [12, 13], and its association with TMD[12, 14-29]. Changes in head posture have been associated with changes in the stomatognathic system, thus head posture is presumed to have an influence in the biomechanical behaviour of the TMJ and associated structures [8, 9, 30-36]. Some studies have suggested the position of the head affects the resting position of the mandible[19, 30, 31, 33, 34, 36-38], increases muscular activity[39], and alters the TMJ internal associations[40]. In addition, a close association between head and cervical posture improvement and the relief of symptoms of TMD has been found [21, 23, 28].

The association between head and cervical posture with TMD has been debated in the literature. It is supposed that either head posture might cause and/or predispose to TMD. Differences of opinion exist in this matter, with some studies supporting the connection between TMD, head and cervical posture [14, 21, 25, 35, 41, 42], but others not [17, 20, 27]. Therefore, a comprehensive systematic review was necessary to critically analyze the information regarding the association of TMD and head and cervical posture. It was hoped that the findings of this systematic review would help guide clinicians on whether or not the evidence is sufficient to indicate an association between the head and cervical posture and intra-articular and muscular TMD for treatment planning in patients with TMD, and also to identify areas needing further research.[43, 44]

4.2 OBJECTIVES

The purpose of this systematic review was to assess the evidence concerning the association between head and cervical posture with intra-articular and muscular TMD.

4.3 METHODS

4.3.1 SEARCH STRATEGY

A computerized database search was performed to identify relevant articles. For this review, the literature was searched for published studies on the association between head and cervical posture with intra-articular and muscular TMD published in all languages according to the search strategy of Dickersin[45]. Studies were searched from 1965 up to and including November 9, 2004, and were obtained through an extensive search of bibliographic databases including Medline (1966- to October week 4, 2004), Embase (1988- to week 45, 2004), Cochrane Library and Best Evidence (1991-third quarter, 2004), ISI web of sciences (1965- November 9, 2004), Pubmed (1966-November 9, 2004), Lilacs (1982-November 9, 2004), and Medline in process (1966 to November week 1, 2004). Key words used in the search were: Posture, head posture, cervical spine or neck, vertebrae, cervical lordosis, craniomandibular disorders or temporomandibular disorders, temporomandibular joint disorders, orofacial pain or facial pain.For details regarding the specific search terms and combinations see

Table 4-1. The selection of these terms were made with the help of a librarian specialized in health sciences databases.

Additionally, literature search was complemented by manually searching the bibliographies of the identified papers, looking for key authors (for example, Rocabado, Sollow, Tallgren, Cook), and consulting key journals (Journal of Orofacial Pain, Cranio, Journal of Oral Rehabilitation, European Journal of Orthodontics, and American Journal of Orthodontics and Dentofacial Orthopaedics).

Table 4-1. Search Results from Different Databases

Database	Keywords	Results	Selected	Included Studies	% of total selected abstracts (12)
PubMed	(1)Temporomandibular joint disorders; (2)orofacial pain; (3) head posture; (4)1 or 2 and 3; (5) cervical spine or vertebrae; (6) #1 OR # 2 AND 5; (7)cervical posture; (8) #1 AND #5 AND #7; (9) #1 or #2 AND #7	177	9	5	41.6
Medline	(1) Temporomandibular joint disorders; (2)cervical vertebrae; (3)head or exp. cephalometry or exp Posture; (4)1 and 2 and 3	74	1	1	8.3
Medline in process	(1) Temporomandibular joint disorders; (2)cervical vertebrae; (3)head or exp. cephalometry or exp Posture; (4)1 and 2 and 3	75	0	0	0
Embase	(1) Temporomandibular joint disorders; (2)cervical vertebrae; (3)head or exp. cephalometry or exp Posture; (4)1 and 2 and 3	16	0	0	0
Web of Science	(temporomandibular disorders or craniomandibular disorders or temporomandibular joint disorder or orofacial pain) and (cervical spine or cervical vertebrae or neck) and (head posture or head position or lordosis or cervical lordosis) DocType=Article; Language=All languages.	7	3	2	16
Lilacs	(1) Temporomandibular; (2) posture; (3) #1 OR #2	7	4	2	16
Cochrane Library	(1)Temporomandibular disorders; (2) Cervical spine; (3) Posture; (4) Lordosis; (5) #1 and # 3; (6) #2 and #3; (7) #5 and #6	2	0	0	0
Manual search		4	4	4	33.3
Total			21	14	
Repeated articles			2	2	
Final		284	19	12	

*** Percentages do not add up to 100% as the same reference could be found in several databases.**

4.3.2 CRITERIA FOR CONSIDERING STUDIES FOR THIS REVIEW

4.3.2.1 Types of Studies

Clinical trials (CTs), cohort studies, case control studies, cross sectional and series of cases studies relating the head and cervical posture with TMD were included in this review.[46]. Case reports and literature reviews were not included. Because of the objective of this systematic review was to analyze the information of the association between head and cervical posture with muscular and intra-articular TMD,, this systematic review was open to all the studies that analyzed this association.

4.3.2.2 Types of Participants

Inclusion in this review was restricted to studies with participants meeting the following criteria: a) humans between 7-60 years old); b) TMD diagnosis; c) no previous temporomandibular joint surgery; d) no history of trauma or fracture in TMJ or craniomandibular system; f) no other serious co-morbid conditions (e.g. cancer, rheumatic disease, neurological problems).

4.3.2.3 Types of Outcome Measures

The primary outcome of interest was measurement of head and cervical posture through body landmarks, pictures or using teleradiographs in patients with TMD.

4.3.3 DATA EXTRACTION

Three independent reviewers screened the abstracts of the publications found in the databases, and, if the abstracts were not available, only the title of the publication was screened for acceptance. When reviewers felt that the abstract or title was potentially useful, copies of the article were obtained and were analyzed by all reviewers regarding inclusion criteria. If there was no consensus between the reviewers and if the publication (evaluated through the abstract) potentially met the inclusion criteria, or if there was inadequate information to make a decision, a copy of the published article was obtained as well. The reviewers analyzed all papers (initially selected by the abstract or title) for the inclusion/exclusion criteria. Each criterion was graded on a yes/no basis – that is, the published paper had to provide enough information to adequately meet the criterion. In order for papers to be evaluated at the next level, the critical appraisal, the paper had to meet all the inclusion criteria on the rating form. When discrepancies occurred between reviewers choosing the included papers, rating forms were compared and reasons identified and a final decision was made, having the agreement of all reviewers.

4.3.4 CRITICAL APPRAISAL

The next step involved rating the final selected studies to determine internal and external validity. This critical appraisal was performed using a tool previously developed [47, 48] and used in previous systematic reviews [49, 50]. This tool considered: study design, control of confounding variables, subjects

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agreement to participate, sample size calculation, validity, reliability of outcomes measurements, blinding, statistical analysis and external validity. At this stage, two reviewers independently evaluated the studies based on specific predetermined criteria. If there was inadequate information in the published papers to allow evaluation of the criteria, the authors of the studies were contacted, via regular mail and/or email, to clarify study design and specific characteristics of every study such as sample size, participation agreement, reliability and validity of the outcomes, and statistical analysis. When the information was received, articles were evaluated with a critical appraisal sheet. When authors did not reply to the questions made by the authors of this systematic review, articles were evaluated with the information available in the article. The criteria were then rated as pass (P), moderate (M) and fail (F) in every category (9 categories in total). The rating system was based on a similar rating system developed by de Vet et al., in 1997[43] and used in previous systematic reviews[49, 50]. The critical appraisal was independently completed by the two reviewers and their results were compared. Any discrepancies were settled through discussion. Finally, every study was graded as weak, moderate, or strong, depending on how many of the critical appraisal criteria were met. All criteria were weighted equally.

4.4 RESULTS

The database search of the literature resulted in a total of 284 articles. Of these 284 articles, 19 were selected as potential studies based on their abstracts. Only 12 studies actually fulfilled the initial criteria after reading the complete article. The kappa for agreement among the reviewers in selecting articles after applying inclusion and exclusion criteria was k= 0.91. When discrepancies occurred in the rating of the paper, reasons were identified and a consensus reached between reviewers. Seven studies were rejected after applying the inclusion/exclusion criteria [18, 51-56].

Comparing the database results, Pubmed obtained the greatest diversity of finally selected articles (41.6%) followed by manual search (33.3%), Web of Science (16%), Lilacs (16%), Medline (8.3%) and finally Embase, Cochrane library, and Medline in Process from which no articles were selected. The different databases repeated some of the articles, except Lilacs which included only Latin-American publications and accounted for a significant percentage (16%) of the finally selected articles.

The primary reasons for study exclusion were: (1) the measurement of head posture or cervical posture was not clear [18, 51, 52, 56]; (2) participant eligibility criteria was not met[55]; (3) the diagnosis of TMD was unclear or nonexistent [54]; and, (4) the study was not experimental research (the article was a “letter to editor”).[53]

Twelve studies met all selection criteria [14, 16, 17, 20-22, 24-27, 29]. Only two authors[27, 29] responded to the mail/email communication and provided further information on the study design and methods. The remaining authors did not provide the information (10 authors). However, the articles were analyzed based on the available information provided by the articles. At the end of critical appraisal stage, there was an agreement of k= 0.815 between raters. Discrepancies were settled through discussion.

Detailed information of the finally selected studies on the study design, participants, interventions and outcomes as well as the study limitations and strengths are summarized in Table 4-2.

4.4.1 CHARACTERISTICS OF THE STUDIES

Of the twelve studies included in the critical review, eleven [14-17, 20, 21, 24-27, 29] were classified as cross sectional studies, and one [22] was classified as case series. However only two of them [17, 22] used random selection in their experimental process. Nine articles [14, 17, 21, 22, 24-27, 29] included patients with mixed TMD (muscular and intra-articular) and one article [27] differentiated among muscular, intra-articular and mixed symptomatology. Three articles [16, 20, 27] analyzed the information from patients with only intra-articular problems (internal derangement of the temporomandibular joint and intra-articular TMD evaluated clinically). Finally two studies [15, 27] evaluated the association between head posture in patients only with a muscular diagnosis (muscular TMD and masticatory muscle hyperactivity respectively)

4.4.2 METHODOLOGICAL QUALITY OF INCLUDED STUDIES

The results for the critical appraisal are presented in Table 4-3. The primary concerns of the studies analyzed by this review were as follows:

a. A non-randomized sample selection process was used (10 of 12 studies).

b. There was inadequate information with regards to the methodology used to measure the head and cervical posture (10 of 12 studies).

c. The sample size calculation and associated power of the studies were not reported (12 of 12). In order to evaluate the sample size, when not reported, the authors of this systematic review calculated the power of the study, if possible, based on the study findings.

d. Outcome measures were not well described in terms of validity, reliability and responsiveness (10 of 12 studies). As well, the authors of the publications did not report intra and/or inter-rater reliability of the assessors responsible for performing the outcome measurements (where applicable).

e. Independent assessors (blinded to group allocation when applicable and also blinded when analyzing the measurements) were not used (7 of 10 studies).

4.4.3 HEAD POSTURE AND MIXED TMD

Nine studies [14, 17, 21, 22, 24, 26, 27, 29] addressed the association of TMD of mixed origin and head and cervical posture. The system of evaluation for TMD was clinical, based on signs and symptoms. The criteria used for most of the studies[17, 22, 24, 27, 29] were: disc derangements evaluated clinically (click), associated muscular disorders determined by pain on palpation, reduced range of jaw opening and deviation of the mandible, and pain in the TMJ area with mandibular movement or spontaneous pain.

Regarding the conclusions established by these studies, seven studies [14, 21, 22, 24-26, 29] reported that an abnormal head and cervical posture was present in patients with TMD, and two studies [17, 27] obtained no differences in head posture between patients and healthy controls. For more details see Table 4-2.

4.4.4 HEAD POSTURE AND INTRA-ARTICULAR TMD

Three articles [16, 20, 27] addressed the association between articular TMD and head and cervical posture. One study[20] used photographs, another[16] used teleradiographs, and the third study[27] used both photographs and teleradiograph to analyze head and cervical posture. According to Hackney et al.[20], who diagnosed the disc displacements through MRI, and Visscher et al.[27] who made a clinical diagnosis of articular TMD, found that there were no differences in head posture between patients with internal derangement and articular disorders (respectively) and a control group. However, D'Attilio et al

[16] found that patients having TMD with disc displacement, verified by MRI, showed a significantly lower lordosis angle (decreased cervical lordosis) than a control group.

4.4.5 Head Posture and Myogenous TMD

Two studies[15, 27] investigated the association between head posture and cervical lordosis and presence of muscular TMD and hyperactivity of the masticatory muscles respectively. One of the studies [27] used photographs and teleradiographs to evaluate head posture, and the other [15]used photographs and landmarks to assess the cervical lordosis.

Visscher et al [27] confirmed patients complaint of pain in the area of masseter and /or temporalis muscles, by pain in the same area on dynamic/static test or active movements. They concluded that patients with muscular TMD did not differ significantly from patients without TMD. Muscular Hyperactivity in the Chiao's study [15] was defined as having pain in at least one masticatory muscle on palpation, along with parafunctional habits and absence of signs and symptoms of intra-articular pathology. These authors conclusions were contradictory and did not reflect the results. However, when the authors of this current systematic review analyzed results of the Chiao et al's study[15] (comparing graphs and values of each group and making the statistical analysis), cervical lordosis was increased in patients with hyperactivity of masticatory muscles as well as in control subjects.

4.5 DISCUSSION

In the present systematic review, few publications were found that addressed muscular and intra-articular TMD and its association with head or cervical posture. Furthermore, few publications met the inclusion criteria for a specific evaluation of the head or cervical posture, as well as a clear diagnosis of muscular and intra-articular TMD.

Readers without a sound understanding of the process (including strengths and weaknesses of systematic reviews) are encouraged to read some about systematic reviews in health sciences [57-60] to fully understand the background assumptions for the present paper.

4.5.1 HEAD POSTURE AND MIXED TMD

Most studies included in this systematic review considered patients with mixed TMD diagnosis, combining signs and symptoms, and sometimes not having clear or defined criteria for TMD classification. Braun [14], for example, stated that TMD diagnosis consisted only of a complaint of jaw pain, jaw dysfunction, daily headaches or neck pain. Sonnensen et al.,[26], divided the signs and symptoms of TMD into 65 categories and also classified subjects according the Helkimo Index. However, the criteria used to define TMD were not clear.

To make clear conclusions regarding head, cervical posture and TMD, more accurate diagnosis and definition of terms is needed. When analyzing the information that exists in the literature, one realizes that the quality of the studies is poor. Most of the studies did not include random sample selection in their process, which could lead to bias. Another factor to consider is study sample size. Four studies[14, 17, 22, 24] had low power and inadequate sample sizes meaning that, internal and external validity are questionable and results cannot be extrapolated to larger populations. Other methodological flaws encountered included incorrect statistical analysis[14, 21, 22, 24], not using a blinded process in the evaluation of outcomes[14, 21, 22, 24], no information on validity[14, 17, 21, 22, 24-27, 29] nor reliability[14, 17, 21, 22, 24, 26, 29] of measurements. (For details of the studies see Table 4-2).

Three studies[21, 26, 29] that used teleradiographs to evaluate head posture found a association between abnormal head and cervical posture and TMD. One study [27] did not find any difference between a group of patients with TMD and a control group.

Sonnensen et al.,[26] evaluated head posture comparing patients having a specific TMD trait with patients without this trait. Children with clicking TMJ and limited jaw mobility had marked forward inclination of the head. However, the control group was not true controlled group, since control subjects also had TMD (but with a different trait). The sample size was small (ranged between 6-15 patients per each comparison), which makes extrapolations difficult because of low statistical power.

Huggare and Raustia [21] found significantly greater craniovertebral and craniocervical angles in a group of patients with TMD expressed compared with control subjects. They reported good power (0.95). However, their statistical analysis was flawed (see Table 4-3 for details). They did have good control of the confounders and divided patients from healthy subjects, analyzing head and cervical posture through teleradiographs. Additionally, Armijo Olivo et al.[29], using teleradiographs, found differences in cervical lordosis, craniocervical spaces, and craniocervical angulation between patients and healthy controls in a study having good power (0.90) with equal sample sizes and clear control of confounders. Nevertheless, this study sample selection was not randomized, with no description of validity or reliability of the measurements. On the other hand, Visscher et al.,[27], found no differences between controls patients and patients with TMD using teleradiographs. Even if the authors did try to differentiate and classify patients clearly with different diagnoses, sample size comparisons were unequal (40 controls and 13 patients with TMD) which makes comparisons unbalanced .Patients were also not randomly selected from a population of patients having TMD, questioning the probability that these subjects represent all patients with TMD.

From the studies that used photographs [14, 24, 27], two studies found a association between head posture and patients with TMD, and one study[27] did not support this conclusion. The study by Visscher et al.,[27] was discussed previously, and the same flaws are applicable. Lee et al[24] found that compared to controls, the head was positioned more forward in patients with TMD. They based their results in a study with good power (0.85), however, methodological problems including incorrect statistical analysis, no blinding process was used and their study did not report the validity nor reliability of the outcomes measures. Additionally, the results obtained by Braun[14] are controversial. This author reported that abnormal forward head posture was related with TMD, however, methodological flaws in the study makes the results questionable (see Table 4-3).

Finally, from the three studies that used landmarks[17, 22, 25], two studies[22, 25] did find a association between head posture and TMD, but one[17] did not find this association. These three studies had similar weaknesses. The description of the method of evaluation of head posture was general, lacking a clear objective measurement. Reliability according to Nicolakis et al.,[25] and Darlow et al., [17] was good, however , reliability of the measurements in the Kritsinely and Shim[22] study was not reported. Validity of the head posture measurement was not reported in any of the studies. Therefore, based on the information provided by these three studies, results are inconclusive.

4.5.2 HEAD POSTURE AND INTRA-ARTICULAR TMD

Three studies [16, 20, 27] analysed the association between TMD of articular origin with head and cervical posture. One study used teleradiographs [16], another used photographs [20] and the third study used both teleradiographs and photographs[27].

Visscher et al.,[27] found no differences between patients with arthrogenous TMD and controls for both photographic and teleradiographic methods. However, this article based its conclusions on a comparison between 11 patients and 62 normal controls. As previously discussed, unequal sample size between control and experimental groups, with lack of randomization in the sample selection, adds uncertainty to the conclusions of this study. In addition, the articular diagnosis was performed clinically as having more pain in dynamic testing than on static testing, pain on lateral or posterior palpation of the temporomandibular joint area and pain during joint play testing, without confirmation of disc status on MRI. It is well established that clinical evaluation does not provide a definitive diagnosis of disc status with approximately one third of asymptomatic volunteers having internal derangement.[61]

Hackney et al.,[20] found no difference in head posture between patients with TMJ internal derangement and control patients. Although the authors confirmed the clinical diagnosis of internal derangement with magnetic resonance imaging (MRI), the sample size, power (0.34), statistical analysis, and lack of reporting validity of outcomes measurements raises concerns about studies conclusions.

Finally, D'Attilio et al[16] found a significantly lower lordosis angle in patients with TMJ internal derangement determined with MRI compared with controls who had normal disc position determined by MRI as well. This means that patients with TMD had a tendency to have an abnormal cervical curvature. They used sufficient sample to have a power of 0.80. Moreover, the diagnosis was performed by a radiologist who was blinded to the patient's allocation, and the cephalometric analysis was shown to be reliable, establishing consistent results. However, this study was cross-sectional in nature and future longitudinal studies are necessary to support their findings.

4.5.3 HEAD POSTURE AND MYOGENOUS TMD

Two studies [15, 27]analyzed the association between myogenous TMD with head posture and cervical lordosis respectively. Both studies found no differences in head posture and cervical lordosis between patients and healthy controls. Comparing patients with muscular TMD and healthy subjects, Visscher et al[27] had a more balanced subject pool comparison (myogenous subject = 63 compared with healthy subject = 62 for teleradiograph analysis; and myogenous subjects = 75 and healthy = 74 for photograph analysis) which improved the consistency of their results. They found that there were no significant differences in head posture between patients with TMD and healthy controls.

Chiao et al., [15] evaluated the cervical lordosis through photographs and landmarks, but the method used to measure the cervical lordosis was imprecise. Moreover, neither the validity nor the reliability of the evaluation for cervical lordosis and for muscular hyperactivity were described. This study had low power (0.20), with a small sample size. The authors did not accurately analyze the results and conclusions were contradictory to results. For example, it was concluded that patients with hyperactivity had increased cervical lordosis when compared with the control group, however, the information provided in the graphs and tables did not confirm this finding.

4.5.4 Limitations of the Study

The findings of this review are specific to the association between muscular, intra-articular and mixed TMD with head and cervical posture. The information obtained from this systematic review was limited by the quality of the studies found. Although attempts to complete possible missing information were made, the authors' response was low. Most of the studies provided a mixed diagnosis with poorly established criteria. Because the objective of this systematic review was to analyze information regarding the association between head and cervical posture with muscular and intra-articular TMD, all studies analyzing this association were included. Attempts were made to obtained articles not found by database searches and included four articles obtained by a manual searching. The studies identified in this systematic review may not represent all existing research in the area, since unpublished research and literature prior to 1965 were not obtained.

4.5.5 Strengths of this Study

This systematic review was the first one investigating the association between muscular, intra-articular, and mixed TMD with head and cervical posture. A comprehensive search for all the published research in this area was

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made including a wide range of years (1965-2004), and considering all available languages.

4.6 CONCLUSIONS

4.6.1 IMPLICATIONS FOR PRACTICE

Most of the studies included in this review were of a poor methodological quality; and therefore, their findings and conclusions must be interpreted with caution. Based on the findings, it is not clear that head and cervical posture is associated with intra-articular and muscular TMD. In the absence of the highest level of evidence, clinicians have to make decisions based on lower levels of evidence.

4.6.2 IMPLICATIONS FOR RESEARCH

More methodologically sound research will be necessary to provide clear conclusions and how to apply the findings to clinical practice. Firstly, it is recommended that investigations that study the association between TMD and head and cervical posture, provide clear diagnosis of the TMD condition in question. Secondly, there is a clear need for well-designed controlled trials investigating the association between head and cervical posture with intra-articular and muscular TMD.

Future investigators should consider the findings of this systematic review when designing future trials and attempt to overcome the limitations of the published studies. Trials should be large enough to be clinically meaningful, adequately powered, and include valid and reliable outcome measures. Furthermore, attempts should be made to blind assessors performing outcome measures and where possible, blind the participants as well. We also recommend that researchers follow the guidelines of the CONSORT[62] statement when designing their study, and when reporting the methods and results sections for publication.

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		external intervention		and reliability) external validity of this results has to be considered with care

- ***statistical power calculated by the authors of this systematic review***
- ***** Information provided by the authors***

Table 4-3. Methodological Scoring of Included Studies by Quality Score.

Study	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*		*Total Score*
A. TMD Subclassification between muscular, articular and mixed diagnosis											
Visscher, CM et. al. (2002)	M	P**	P**	F	P	P	P**	M	F	2F, 2M,5P	WEAK
B. Mixed TMD diagnosis											
Armijo S, et al (2001)	M	P**	P**	P	F	P**	P**	M	P**	1F,2M,6P	WEAK
Darlow LA, Pesco J and Greenberg MS (1987)	M	P	F	F	F	P	P	M	M	3F,3M,3P	WEAK
Lee, W. Y., Okeson, J. P., & Lindroth, J. and (1995)	M	P	F	M	F	M	P	F	F	4F,3M,2P	WEAK
Nicolakis, P et al. (2000)	M	P	F	M	F	P	P	M	P*	2F,3M,4P	WEAK
Huggare, J. A., & Raustia, A. M. (1992).	M	P	F	M	F	F	P	F	F	5F,2M,2P	WEAK
Sonnesen, L., Bakke, M., & Solow, B. (2001a).	F	M	F	F	P	F	P	F	M	5F,2M,2P	WEAK
Braun, B. L. (1991).	M	F	F	F	M	F	P	F	F	6F,2M,1P	WEAK
Kritsineli M, Shim YS.(1992).	M	F	F	F	F	F	P	F	F	7F,1M 1P	WEAK
C. Articular TMD diagnosis											
D'Attilio M, Epifania E, Ciuffolo F, et al (2004).	M	P	F	M	P	P	P	M	M	1F,4M,4P	WEAK
Hackney, J., Bade D., & Clawson, A. (1993).	M	P	F	F	M	M	P	F	F	4F,3M,2P	WEAK
D. Myogenous TMD diagnosis											
Chiao L, Guedes Z, Vieira M.(2003)	M	P	M	F	F	F	P	F	M	4F,3M,2P	WEAK

*** Information provided by the authors; F=Fail, M=Moderate, P=Powerful*

1) *Type of study;* 2) *Confounders;* 3) *Agreement to participate;* 4) *Sample size;* 5) *Data collection Methods;* 6) *Blinding;* 7) *Subjects starting and finishing the study;* 8) *External Validity;* 9) *Statistical Analysis.*

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5 CHAPTER 5

HEAD AND CERVICAL POSTURE IN PATIENTS WITH TEMPOROMANDIBULAR DISORDERS (TMD)

5.1 INTRODUCTION

Cervical and head posture and its relation with musculoskeletal painful conditions such as neck pain and temporomandibular disorders (TMD) have been of interest to researchers and clinicians. According to the literature, altered posture of head and neck might cause and/or predispose to painful conditions through altering the biomechanics and neuromuscular system of the craniocervical region [1, 2]. Head and neck posture has been biomechanically related to the mandibular [3-10] and condylar positions of the Temporomandibular Joint (TMJ) [11] and also has been found to influence the muscular activity of the masticatory and neck muscles.[2, 12] In addition, forward head posture, one of the most common alterations of the head/cervical posture, has been related to increased load in the cervical spine [1] and changes in the cervical soft tissues length and strength.[10] There is a growing body of literature investigating these associations. A recent systematic review [13] investigating the relationship between head and cervical posture and TMD found no conclusive results regarding this relationship. Thus, the evidence is still questionable and there are no definitive results supporting this connection. Most of the analyzed studies lacked a clear clinical diagnosis to identify the condition, were low powered (i.e.

using small sample sizes), had inappropriate statistical analyses which impaired the accuracy of the results, did not report the reliability of the measurements and did not blind the assessment. The systematic review also identified insufficient research investigating the association between head/cervical postures in subjects with myogenous TMD. Only two studies included subjects with myogenous TMD. The present study was designed to address some of the shortcomings identified by the systematic review. It included a group of patients with myogenous TMD, a sample size calculation was performed, the reliability of the measurements was assessed, and it included a blinded assessment of the measurements to avoid bias in the results.

5.2 OBJECTIVES

1. The main objective of this study was to determine whether patients with myogenous TMD had different head and cervical posture measured through angles commonly used in clinical research settings(tragus-C7-horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder), when compared to healthy individuals.

The secondary objectives of this study were:

2. To determine whether patients with mixed TMD (mixed symptomatology: muscular and articular) had different head and cervical posture measured through angles commonly used in clinical research settings (tragus-C7-

horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder), when compared to healthy individuals;

3. To determine whether patients with myogenous TMD had different head and cervical posture measured through angles commonly used clinical research settings (tragus-C7-horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder), when compared with subjects with mixed TMD;

4. To determine whether there was an association between postural variables (tragus-C7-horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder angles) and jaw disability;

5. To determine whether there was an association between postural variables (tragus-C7-horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder angles) and neck disability;

6. To determine whether there was an association between postural variables (tragus-C7-horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder angles) and pain intensity.

7. To determine the intra-rater and inter-rater reliability of the postural measurement procedure.

5.3 RESEARCH HYPOTHESES

The following hypotheses were investigated in this study:

1. Patients with myogenous TMD will have altered head and cervical posture measured through angles commonly used in clinical research settings (i.e. tragus-C7-horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder), when compared to healthy individuals.

2. Patients with mixed TMD (mixed symptomatology: muscular and articular) will have altered head and cervical posture measured through angles commonly used in clinical research settings (i.e. tragus-C7-horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder), when compared to healthy individuals;

3. Patients with myogenous TMD will have different head and cervical posture measured through angles commonly used clinical research settings (i.e. tragus-C7-horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder), when compared with subjects with mixed TMD.

4. There will be a strong association between postural variables (i.e. tragus-C7-horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder angles) and jaw disability;

5. There will be a strong association between postural variables (i.e. tragus-C7-horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder angles) and neck disability.

6. There will be a strong association between postural variables (i.e. tragus-C7-horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder angles) and pain intensity.

7. The intra-rater and inter-rater reliabilities of the postural measurement procedure will be good.

5.4 METHODS

5.4.1 SUBJECTS

A convenience sample of subjects who attended the TMD/Orofacial Pain Clinic at the School of Dentistry, Faculty of Medicine and Dentistry, University of Alberta and healthy students and staff at the University of Alberta was recruited for this study using advertising in different faculties and the surrounding areas (appendix 1). Sample size calculation for this study was based on multivariate analysis of variance using the guidelines proposed by Stevens (using $\alpha= 0.05$, $\beta= 0.20$, power = 80%, and a moderate effect size:0.5).[14] Based on the calculation, approximately 50 subjects were needed per group. Subjects were continually recruited until the total sample of subjects was obtained.

The same inclusion/exclusion criteria for healthy as well as subjects with TMD described in Chapter 3 are applicable to this study

5.4.2 CLINICAL ASSESSMENT

Subjects underwent a clinical examination by a physical therapist with 14 years of experience in musculoskeletal rehabilitation and treatment of temporomandibular disorders (principal investigator) to determine if they met the inclusion criteria or were excluded by the exclusion criteria for this study. Clinical examination followed the guidelines of the diagnostic research criteria for TMD.[15] Briefly, subjects were examined for pain in masticatory muscles, TMJ joint, and also TMJ range of motion (Appendices 2, 3, and 8).

If the physical therapist felt the subject did not meet the inclusion criteria, the subject was excluded of the study. Subjects were informed about the study and signed an informed consent in accordance with the University of Alberta's policies on research using human subjects (Appendices 4 and 5).

5.4.3 Instrumentation and Procedures

5.4.3.1 General Considerations

Demographic data were collected on all subjects who satisfied the inclusion criteria including age, weight, and height. In addition, all subjects were asked to report specific characteristics regarding their jaw problem (i.e. onset, duration of symptoms, treatments received). All subjects were asked also to report their intensity of pain in the jaw (VAS), [16-20] and also complete the Neck Disability Index (NDI) (appendix 6), [21, 22] the Jaw Function Scale (LDF-TMDQ/JFS) (appendix 7),[23] and a history questionnaire for jaw pain used by the RDC/TMD (appendix 8).[15] These tools have been described previously in Chapter 3.

5.4.3.2 Protocol for Head Posture Photograph

A lateral photograph was taken from each subject with the head in the self–balanced position [24, 25]. The self-balanced position was obtained with each subject standing with his/her visual axis horizontal relative to the floor, with no external intervention or modification of his/her posture [24, 25]. The objective of this procedure was to obtain a position of the head and cervical spine in the sagittal plane that was determined by the subject's own postural system. The subject was asked to be shoeless, in standing position, with the eyes looking forward and with the teeth in occlusion. It was necessary to describe the position of the feet as "a comfortable distance apart and slightly diverging". Each patient was asked to breathe in deeply (inhale), and then exhale, a process which was repeated until the patient felt comfortable and relaxed in a habitual posture (i.e. without any external intervention). The patient was asked to maintain this self-balanced position without correcting it when the photograph was taken.

A digital camera (CANON PowerShot A570IS), positioned on a tripod at a distance of 183 cm from the subject, was used to take the photographs. The axis of the lens was placed perpendicular to the sagittal plane of the subject at a height that corresponded with the seventh cervical vertebra (C7). An anatomical marker was positioned on the C7 fixed with double-sided medical tape. A free hanging plumb line indicated the true vertical line on the photographs. Two photographs were taken for each individual allowing one minute approximately between each photograph. The average of each of the measurements obtained from the two photographs was used for analysis.

Alcimagen ®software (Instrumental Concept and Movement Analysis Laboratory, Uberlândia, Minas Gerais, Brazil) specifically designed to measure angles and used in previous studies demonstrating excellent intra-rater reliability (ICC=0.99),[26, 27] was used in this study to measure four angles in the photographs: 1) eye-tragus-horizontal, 2) tragus-C7-horizontal, 3) pogonion-tragus-C7, and 4) tragus-C7-shoulder. For more details of these angles see Figure 1. These angles were chosen because they have been commonly used in other studies and in clinical research settings to evaluate the posture of the craniocervical region [28-33]. Thus, this study tried to mimic as closely as possible the clinical situation for evaluating head and neck posture. These angles have face and content validity to determine posture of the craniocervical region. [34]

All the measurements were performed by a single trained rater, a dentist specialist in orthodontics, blinded to the subjects' group status, following the same procedure for all photographs. For intra-rater reliability, 30 randomly chosen photographs were measured in the same way in a second time by the same trained rater conducted at least 1 month apart. A second rater (principal investigator) only participated in the inter-rater reliability analysis, measured 30 randomly chosen photographs to establish inter-rater reliability of the analyzed measurements (power=0.90, α=0.05 using intra class correlation coefficient for inter-rater reliability).[35, 36]

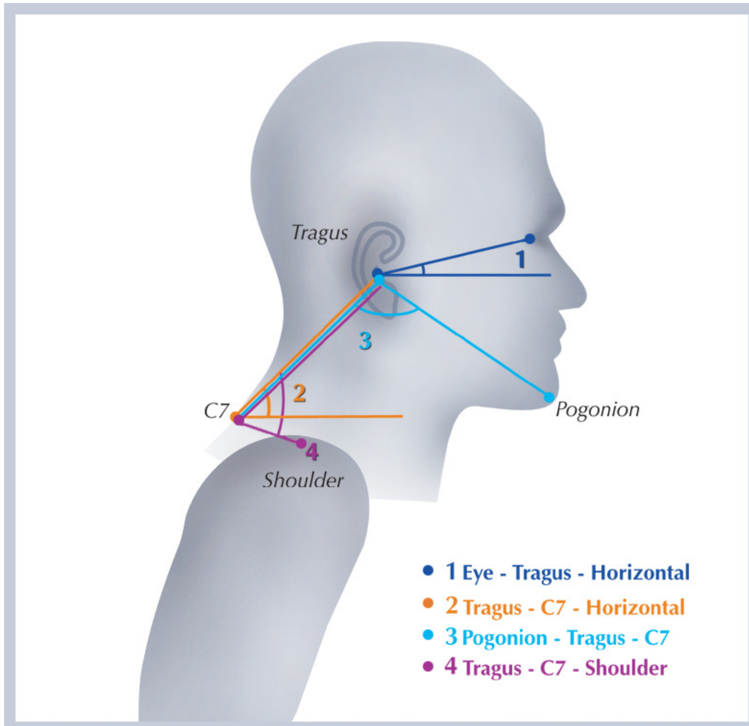

Figure 5-1. Postural Variables Analyzed in this Study

5.5 ANALYSIS

The data on postural variables were analyzed descriptively (i.e. mean, standard deviation) and explored for normality with histograms, Q-Q plots and Kolmogorov-Smirnov tests. A one way MANOVA test was used to analyze the difference between angles among groups. Paired comparisons using Bonferroni Post hoc tests were used to evaluate the differences between postural variables (objectives 1, 2 and 3). Spearman rho test was used to evaluate the association between postural variables, jaw disability, and pain intensity (objective 4 and 6). Multiple regression analysis was used to analyze the association between neck disability and head and neck posture variables (objective 5). The Intraclass-correlation coefficients were calculated using a two-way mixed effects model, single measure reliability (ICC (3, 1) with absolute agreement and alpha level set at 0.05 to evaluate the intra-rater and inter-rater reliability of the measurements for all the analyzed angles following the guidelines of Shrout and Fleiss [37](objective 7). In addition, Standard error of the measurement was calculated following the guidelines established by Weir.[38]. The level of significance was set at $\alpha = 0.05$. SPSS version 17 and STATA version 10 statistical programs were used to perform the statistical analyzed. The analysis was performed blinded to group condition.

5.6 RESULTS:

5.6.1 SUBJECTS

A total number of 172 subjects were assessed for inclusion in this study. A total of 18 subjects were excluded. The main reasons for exclusion were: being not totally healthy (9 subjects), being older than 50 years old (2 subjects), having a neurological disease (1 subject), having cancer (1 subject), or the pain score was lower than 30 mm in the visual analogue scale (5 subjects).

One hundred and fifty four participants (154) provided data for this study. From these 154 subjects, 50 subjects were healthy, 55 subjects had myogenous Temporomandibular disorders (TMD) and 49 subjects had mixed TMD.

The general demographics for each group are as follows (Table 5-1):

Table 5-1. Descriptive Statistics of Height, Weight, and Age for all Subjects by Group (i.e. Myogenous TMD, Mixed TMD, and Healthy Subjects)

	Group	Mean	Std. Deviation	N
Height (cm)	**Mixed TMD**	**166.30**	**5.89**	49
	Healthy	**165.26**	**6.64**	50
	Myogenous TMD	**162.04**	**19.66**	55
Weight (kg)	**Mixed TMD**	**71.95***	**15.58**	49
	Healthy	**64.02**	**12.35**	50
	Myogenous TMD	**66.24**	**17.83**	55
Age (years)	**Mixed TMD**	**30.88**	**8.19**	49
	Healthy	**28.28**	**7.26**	50
	Myogenous TMD	**31.91**	**9.15**	55

*** Significantly different when compared with healthy subjects at α=0.05**

5.6.2 SAMPLE CHARACTERISTICS

There were no significant differences in the sample in age and height. However, weight was significantly different between healthy subjects and subjects with mixed TMD (mean difference 7.9 kg [95%CI 0.38, 15.47] p=0.036). No weight differences were found between healthy subjects and subjects with myogenous TMD and between subjects with myogenous and mixed TMD.

The descriptive data of the specific clinical characteristics of the subjects with TMD can be found in Table 5-2.

Table 5-2. Clinical Characteristics for all Subjects by Group (i.e. Myogenous TMD, Mixed TMD, and Healthy Subjects)

	Group	Mean	Std. Deviation	N
Duration of complaint (years)	Mixed TMD	7.6*	6.3	49
	Healthy	0.00	0.00	50
	Myogenous TMD	6.5*	6.6	55
Pain Intensity (VAS) (0-100 mm)	Mixed TMD	49.7*	15.8	49
	Healthy	0.00	0.00	50
	Myogenous TMD	46.3*	16.2	55
Jaw Function Scale Score (Points) 10-50	Mixed TMD	22.78*	7.05	49
	Healthy	10.12	0.39	50
	Myogenous TMD	19.13*†	6.55	55
Neck Disability Index (Points) 0-50	Mixed TMD	13.02*	6.99	49
	Healthy	1.58	1.43	50
	Myogenous TMD	10.75*	5.67	55

*** Significantly different when compared with healthy subjects at α=0.05**
† Significantly different when compared with subjects with mixed TMD at α=0.05

In general, subjects with TMD (mixed and myogenous) were significantly different from healthy subjects in all symptom characteristics (i.e. pain intensity, duration of complaint, Neck Disability Index score and Jaw Disability score). Subjects with mixed TMD were similar to subjects with myogenous TMD in most of the general characteristics such as years of complaint (duration of complaint) and pain intensity ($p>0.05$). The average pain intensity on VAS scale for patients with myogenous TMD was 46.3 mm and 49.7 mm for subjects with mixed TMD. Regarding years of complaint, most of the patients had a long history of pain with an average of 7.6 years of pain for subjects with mixed TMD and an average of 6.5 years for subjects with myogenous TMD.

Related to the level of disability of the subjects with TMD, both groups did not present with a high level of disability either in the neck or in the jaw. The maximum score for the Neck Disability Index is 50, and the subjects having mixed TMD only had an average of 13.02 points and the subjects with myogenous TMD had 10.75 points. Both values are considered only mild neck disability.[22] Related to the Jaw Function Scale, the maximum score is 50 points and the average obtained by the subjects with TMD was 20.74 for subjects with mixed TMD and only 17.36 for the subjects with myogenous TMD. Based on these two scales, the severity for both types of disability in this sample of patients was not severe.

The Jaw Disability score was statistically significantly higher for subjects with mixed TMD compared to myogenous TMD subjects (mean difference 3.7 points, p=0.003 [95%CI 1.0, 6.3]). Neck Disability scores were not statistically significantly different between subjects with mixed TMD when compared with subjects with myogneous TMD, however, subjects with mixed TMD presented with a higher disability score than the subjects with myogenous TMD (mean difference 2.3 points).

5.6.3 POSTURAL ANGLE COMPARISONS BETWEEN SUBJECTS WITH MYOGENOUS TMD, MIXED TMD AND HEALTHY SUBJECTS.

The descriptive data for all analyzed postural variables and groups can be found in Table 5-3. A MANOVA test used to analyze the difference between angles among groups determined that there were differences in the postural angles among groups (Wilks' Lambda=272.0 $p<0.05$). The univariate analysis determined that the only angle that reached statistical significance among groups was the eye-tragus-horizontal ($F=3.03$ $p=0.040$). Pair wise comparisons determined that a mean difference of 3.3º, [95% CI 0.15, 6.41] p=0.036 existed when comparing subjects with myogenous TMD to healthy subjects (Table 5-4). Patients with myogenous TMD have higher mean values for this angle compared with healthy subjects. The remaining angles did not reach statistical significance.

Table 5-3. Descriptive Statistics for Postural Variables Among Groups

	Group	Mean	Std. Deviation	N
Tragus-C7-horizontal angle (in degrees)	**Mixed TMD**	**50.74**	**6.10**	49
	Healthy	**52.46**	**5.11**	50
	Myogenous TMD	**53.05**	**5.46**	55
Eye- Tragus-Horizontal angle (in degrees)	**Mixed TMD**	**20.31**	**5.46**	49
	Healthy	**18.79**	**5.64**	50
	Myogenous TMD	**21.39***	**5.17**	55
Pogonion-Tragus-C7 angle (in degrees)	**Mixed TMD**	**93.46**	**7.16**	49
	Healthy	**90.11**	**6.63**	50
	Myogenous TMD	**92.12**	**6.80**	55
Tragus-C7-Shoulder angle (in degrees)	**Mixed TMD**	**90.99**	**13.40**	49
	Healthy	**95.84**	**12.80**	50
	Myogenous TMD	**94.62**	**13.36**	55

The angles are measured in degrees
*** Significantly different when compared with healthy subjects at α=0.05**

Table 5-4. Pair wise Comparisons Among Subjects with Mixed TMD, Myogenous TMD, and Healthy Subjects in Postural Variables.

Dependent Variable	Group	Group	Mean Difference	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
Tragus-C7-Horizontal angle (in degrees)	Mixed TMD	Healthy	-2.18	1.32	0.307	-5.39	1.03
		Myogenous TMD	-2.03	1.248	0.320	-5.05	1.0
	Healthy	Myogenous TMD	0.15	1.29	1.000	-2.97	3.273
Eye- Tragus-Horizontal angle (in degrees)	Mixed TMD	Healthy	1.16	1.33	1.000	-2.06	4.37
		Myogenous TMD	-2.13	1.25	0.274	-5.16	0.904
	Healthy	Myogenous TMD	-3.28*	1.29	0.036	-6.413	-0.155
Pogonion-Tragus-C7 angle (in degrees)	Mixed TMD	Healthy	3.60	1.61	0.08	-0.31	7.51
		Myogenous TMD	1.04	1.52	1.00	-2.64	4.72
	Healthy	Myogenous TMD	-2.56	1.57	0.317	-6.36	1.24
Tragus-C7-Shoulder angle (in degrees)	Mixed TMD	Healthy	-6.07	3.06	0.15	-13.50	1.36
		Myogenous TMD	-5.92	2.89	0.127	-12.93	1.08
	Healthy	Myogenous TMD	0.14	2.98	1.000	-7.09	7.38

Based on estimated marginal means
a. Adjustment for multiple comparisons: Bonferroni.
*. The mean difference is significant at the 0.05 level

5.6.4 Association between Postural Variables, Pain Intensity, Jaw Disability and Neck Disability

Pogonion-Tragus-C7 angle was significantly, although weakly associated with the Jaw Function Scale and pain intensity (r=0.19 and r=0.22 respectively). The Eye- Tragus-Horizontal angle also was significantly but weakly associated with Jaw Function Scale (r=0.18). No other postural variable was significantly correlated with jaw disability measured through Jaw Function Scale (LDF-TMDQ or JFS)(30) and with pain intensity measured through visual analogue scale (VAS) (Table 5-5).

No individual postural variable was significantly correlated with neck disability measured through the Neck Disability Index [29] ($F(7,146)=2.99$; $p=0.058$; R- squared=0.12) (Table 5-6). When the regression models for these variables were analyzed, only 12% of the variance of the neck disability could be explained by the postural variables.

Table 5-5. Correlations between Jaw Function Scale, Pain Intensity and Postural Variables.

		Jaw function Scale Score	Pain Intensity
C7-Tragus-Horizontal angle	**Correlation Coefficient**	**-0.005**	-0.064
	Sig. (2-tailed)	**0.953**	0.432
	N	**154**	154
Eye- Tragus-Horizontal angle	**Correlation Coefficient**	**0.18***	0.16
	Sig. (2-tailed)	**0.030**	0.053
	N	**154**	154
Pogonion-Tragus-C7 angle	**Correlation Coefficient**	**0.19***	0.22**
	Sig. (2-tailed)	**0.018**	0.006
	N	**154**	154
Tragus-C7-Shoulder angle	**Correlation Coefficient**	**-0.11**	-0.01
	Sig. (2-tailed)	**0.179**	0.078
	N	154	154

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

Table 5-6. Multiple Regression Analysis. Association between Neck Disability and Postural Variables

Neck Disability	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
TragC7Hor	0.09	0.18	0.47	0.638	-0.27	0.45
EyetragusHor	0.08	0.16	0.47	0.640	-0.25	0.40
PogTragC7	0.08	0.17	0.46	0.649	-0.26	0.41
Tragc7Should	-0.07	0.05	-1.47	0.144	-0.17	0.03
Height	-0.03	0.11	-0.28	0.784	-0.24	0.18
Weight	0.06	0.04	1.33	0.186	-0.03	0.14
Age	0.17	0.07	2.33	0.021*	0.03	0.31
_cons	-2.11	28.88	-0.07	0.942	-59.19	54.98

TragC7Hor=Tragus-C7-Horizintal angle; EyetragusHor=Eye-Tragus-Horizontal angle; PogTragc7=Pogonion- Tragus-C7 angle;Tragc7Should=Tragus-C7-Shoulder angle;
Neck Disabil=Neck Disability Index
* Significant at α=0.05

5.6.5 *INTRA AND INTER RATER RELIABILITY*

Intra-rater and inter-rater reliabilities were "excellent" with ICC values ranging from 0.993 to 0.998.[47] (Table 5-7 and Table 5-8). The Standard Errors of Measurements (SEM) were also small ranged from 0.31 to 1.99 degrees.

Table 5-7. Intra-rater Reliability Analysis. Intraclass Correlation Coefficient for all Postural Angles Analyzed.

Angles	SEM	Intraclass Correlation	95% Confidence Interval	
			Lower Bound	Upper Bound
Tragus-C7-horizontal	0.31	0.997	0.990	0.999
Eye-tragus-horizontal	0.46	0.993	0.984	0.996
Pogonion-tragus-C7	0.49	0.995	0.986	0.998
Tragus-C7-shoulder	1.81	0.984	0.967	0.992

Two-way mixed effects model where people effects are random and measures effects are fixed.
Intraclass correlation coefficients using an absolute agreement definition.
SEM= Standard error of Measurement
ICC= Single Measures

Table 5-8. Inter-rater Reliability Analysis. Intraclass Correlation Coefficient for all Postural Angles Analyzed.

Angles	SEM	Intraclass Correlation	95% Confidence Interval	
			Lower Bound	Upper Bound
Tragus-C7-horizontal	0.38°	0.994	0.965	0.998
Eye-tragus-horizontal	0.57°	0.984	0.943	0.994
Pogonion-tragus-C7	0.93°	0.980	0.931	0.992
Tragus-C7-shoulder	1.99°	0.947	0.347	0.986

Two-way mixed effects model where people effects are random and measures effects are fixed.
Intraclass correlation coefficients using an absolute agreement definition.
SEM= Standard error of Measurement
ICC= Single Measures

5.7 DISCUSSION

The main objective of this study was to determine whether patients with myogenous TMD had a different head and cervical posture when using angles commonly measured in clinical research settings compared to healthy individuals. In addition, the secondary objectives were 1) to determine if there were any differences in head and cervical posture between subjects with TMD (myogenous and mixed TMD), and 2) between subjects with mixed TMD and healthy individuals.

According to the results of this study, only the craniocervical posture, measured through the eye-tragus-horizontal angle, was statistically significantly different between patients with myogenous TMD when compared to healthy subjects. This result partially supports the main hypothesis of this study (hypothesis 1), indicating that individuals with myogenous TMD had a more extended head position (in the craniocervical region) than healthy subjects. This could indicate a more forward head position and a biomechanical adaptation of the craniocervical region. Forward head posture has been shown to affect the resting position of the mandible [3-10], to increase masticatory muscular activity [2, 12], and to alter the TMJ internal associations [11]. Based on this evidence, forward head posture has been related to temporomandibular disorders. However, the difference found in the present study between both groups (i.e. myogenous TMD and healthy subjects) was only 3.3º. The small difference found between these groups is probably not clinically significant. It is unlikely that clinicians, through routine postural evaluation, would be able to consistently detect this small difference. Clinicians generally use clinical observation or in some cases, pictures to evaluate posture.[40] It is very unlikely that such a small difference, as the one found in this study, would be used as a criterion for determining progression or change in posture.

No other postural angles such as tragus-C7-horizontal, pogonion-tragus-C7, or tragus-C7-shoulder were statistically significantly different between myogenous TMD and healthy subjects. These results were in agreement with the results of Visscher et al., [41] and Chiao et al.[42]. These studies were the only studies available which investigated head/cervical posture in subjects with myogenous TMD. They found no differences in head posture and cervical lordosis between patients and healthy controls. Visscher et al.[41], used the same angle used in the present study, however, Chiao et al., [42] used a more general way to evaluate posture which lacked clarity and could not be directly compared to the results of the present study. According to the results of Visscher et al.[41], the tragus-C7-horizontal angle was 52.3±4.5º for healthy subjects and 52.7±5.7º for subjects with myogenous TMD. The present study found similar results (52.45 ±5.10º for healthy subjects and 53.04±5.4º for subjects with myogenous TMD) which indicated that there is consistency in these results across studies.

Since the present study investigated other variables not explored in other previous published research, comparisons are difficult. For example, the eye-tragus-horizontal angle has not been used in other studies investigating posture in subjects with myogenous TMD, although it has been used to compared subjects with neck pain and healthy subjects. Silva et al., [28] reported that healthy subjects presented a mean of 18.8°± 7.7° and subjects with neck pain 21.0°± 6.4° and Harrison et al., [43] reported similar results (patients 21.6°±6.4°; controls, 18.8°± 4.2°) using the same clinical method to measure posture. The results of the present study are in agreement with both group results mentioned above. Healthy subjects had 18.78°± 5.64° and subjects with myogenous TMD had 21.39°±5.17° and subjects with mixed TMD had 20.31°±5.41°.

Regarding the relationship between cervical/head posture and the mixed symptomatology of TMD, no significant differences in any of the postural variables between subjects with mixed TMD and healthy subjects or myogenous TMD were identified in the present study. These results do not support the second and third hypothesis of this study. The results found in this study are not in agreement with the majority of the studies investigating the head/cervical posture in subjects with mixed TMD. Seven [44-50] out of nine studies analyzed in a recent systematic review, reported that an abnormal head and cervical posture was present in patients with TMD (forward head posture), and only two studies [41, 51] obtained no differences in head posture between patients with mixed TMD and healthy controls. All of these studies were rated as methodologically weak in this systematic review, which indicates that their results should be interpreted with caution. In addition, the systematic review pointed out that the use of different definitions for TMD as well the use of different methods to measure posture (radiographs, photographs and landmarks) could have accounted for the difference in results.

From the studies using photographs [41, 44, 47] to analyze posture in patients with mixed TMD, two studies [47, 52] found an association between head posture and patients with mixed TMD, while one study [41] did not support this conclusion. The three studies used the tragus-C7-horizontal angle, one study [52] used the eye-tragus-horizontal, and the other one used the C7-shoulder horizontal angle. Lee et al[47] and Braun [52] found the tragus-C7-horizontal angle was larger in control subjects than patients with mixed TMD (54.1°±4.5° for control subjects and 51.4°± 5.5° for subjects with mixed TMD and 55.36°±4.5° for control subjects and 48.22°± 3.17° for subjects with mixed TMD respectively) indicating a more forward head posture than healthy subjects. Both studies found a difference in this angle of about 2.7° to 7.14°. Further research is needed to determine whether these statistically significant differences are indeed clinically meaningful. As indicated by Falla et al.,[53] subtle changes in head/cervical posture over time (about 4°) could reflect poor muscle control of the deep cervical flexor muscles when evaluating sustained postures in patients with pain in the upper quarter. Thus, as pointed by Kraus,[54] a more functional evaluation such as a dynamic evaluation of the posture between patients with TMD and healthy controls could add to the understanding of the muscular impairments of these patients and also explain more accurately the symptomatology in these patients.

Methodological problems pointed out in the systematic review regarding the analyzed studies investigating posture in patients with mixed TMD, including incorrect statistical analysis, no blinding process used for measuring postural variables and low power made the results of these studies questionable. The study by Visscher et al.,[41] was the only one that did not find any difference between the tragus-C7-horizontal angle between patients with mixed TMD and healthy subjects (52.8.± 7.4 for subjects with mixed TMD and 52.3°±4.5° for control subjects).These results are in agreement with the results found by the present study, however, since Visscher et al. [41] used unequal sample size comparisons (45 controls and 15 patients with TMD), one may question whether these results could be found in a larger number of people with mixed TMD.

One interesting finding from a study performed by Visscher et al., [55] was that healthy individuals showed a wide range of cervical spine postures (i.e. lordotic, straight, or reversed cervical spine). This indicates that subjects even without a history of symptoms of the craniocervical region could present different postural patterns which cannot be considered pathological or predisposing to musculoskeletal pain. The present study also showed large postural variation in healthy subjects. The results by Visscher et al.,[55] could explain in part, the results of this study. Healthy subjects presented similar angles to the group of patients. However, patients may have had less capacity to adapt and to support loads than healthy subjects and thus could develop pain. However, this capacity to adapt could be influenced by other factors (e.g. psychological, physical, and social) not explored in this study. Future studies should look at multifactorial models to explain more efficiently the development of pain in conditions such as TMD.

The level of jaw and neck disability of the patients included in the present study was considered mild to moderate, even though the included subjects with TMD had a long history of TMD pain. This could also explain in part the results obtained by this study since the level of disability was not great enough to have an impact on function or physical impairments generally found in subjects with pain. Further research looking at subjects with more severe levels of disability and different types of TMD are needed.

Even though jaw disability and pain intensity had significant correlations with some of the postural variables, the magnitude of these relationships was very weak (r=0.18, r=0.19, and r=0.22) which does not support the 4th and 6th hypotheses of this study. In addition, postural variables were not significantly related to neck disability when adjusted for age, height and weight. These results do not support the fifth hypothesis of this study. When the regression models for these variables were analyzed, only 12% of the variance could be explained by the postural variables. This meant that jaw disability, for example, could be explained by other variables that were not accounted for in these models. The fact that postural variables were not related to pain intensity has been suggested by other studies [53, 56, 57]. For example, in a recent study, Falla et al., [53] found that improvements in forward head posture (i.e. better ability to maintain upright position of the cervical spine) was not linked with a decrease in pain and disability in patients with neck pain. This fact points out that perhaps changes in pain and disability are more complex constructs that depend, as mentioned earlier, on different factors other than postural variables.

The present study used photographic analysis to evaluate posture using surface anatomical markers. Even though this technique was found in this study to have excellent reliability for quantifying these postural variables, precise conclusions about the alignment of the cervical spine and head as shown in radiographs cannot be inferred. More research in this area to determine the validity and sensitivity of the angles measured on photographs is warranted.[40]

This study was designed to minimize bias regarding data collection and analysis methods. An adequate sample size for all groups of subjects, a clear clinical diagnosis to determine subjects' symtomatology, the use of a randomized order to analyze data, as well as randomly selection of photographs to be used for the reliability analysis, and blinding of the measurements made the results of this study strong.

5.8 CONCLUSION

According to the results of the present study, craniocervical posture measured using the eye-tragus-horizontal angle was significantly different statistically between patients with myogenous TMD when compared to healthy subjects. This indicates a more extended position of the head (craniocervical region) in this group of patients. However, the difference was very small (3.3º) and was judged to be not clinically significant. Postural variables were not significantly related with neck disability, jaw disability and pain intensity.

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6 CHAPTER 6

MAXIMAL STRENGTH OF THE CERVICAL FLEXOR MUSCLES IN PATIENTS WITH TEMPOROMANDIBULAR DISORDERS

6.1 INTRODUCTION

The relationship between the cervical spine and craniofacial area has been studied for many years. Anatomical, biomechanical, physiological, and clinical connections have been established between the cervical spine and craniofacial region.[1] Clinically, cervical spine dysfunction (CSD) has been reported to be associated with TMD.[2-5]

Cervical spine dysfunction (CSD) has been defined as a collective term covering a number of clinical problems of the musculoskeletal structures of the cervical spine such as facet joints and muscles. Neck pain is often the main symptom of cervical spine dysfunction affecting the joints or periarticular tissues surrounding the cervical spine. Several studies have found that subjects with TMD presented with CSD and subjects with CSD presented with TMD. [3, 5-11] Specific symptoms arising from the cervical spine are present in subjects with TMD such as tenderness of the neck and shoulder muscles[10] and increased resting electromyography activity of cervical muscles.[12]

The association between TMD and CSD is hypothesized to occur because there is an interconnection between the trigeminal nerve and the first cervical nerve roots in the trigeminal cervical nucleus. Extensive research in animals has confirmed this neuroanatomical and physiological connection. [13-18]

CSD has only been subjectively evaluated through a general clinical examination of the cervical spine. Most of the studies have evaluated CSD through presence of signs and symptoms in the neck along with palpation of tenderness of muscles. More specific cervical muscular impairments in the cervical spine such as alterations of the strength of the cervical muscles, however, have not been explored in the literature and it is unknown if these impairments are associated with TMD.

Strength has been defined as: "the ability of contractile tissue to produce tension and resultant force based on the demands placed upon the muscle. [p.(59-60)] [19] According to several authors, [20-22] if a decrease in strength exists, impairment of function as well as disability and an increase in risk of dysfunction could be present. Several factors could affect strength such as injury, immobilization, disuse, inactivity and pain. Pain has been considered one of the important factors affecting muscular strength. Strength has been considered one of the main elements of muscle performance along with power and endurance.[19] According to Dvir & Prushansky, [23] the evaluation of the strength in the field of rehabilitation is vital since quantitative strength scores are used as outcome parameters to determine muscular impairment and guide treatment decisions. In addition, strength measurements are used as a parameter of change/improvement of a condition in the course of treatment. In addition, an improvement in strength has been connected with improvements in function.[24-27] Cervical flexor muscles have been found to be affected in neck-related disorders such as neck pain,[20, 28] whiplash associated disorders (WAD)[21, 29] and cervicogenic headache [30, 31]. However, no studies investigating the strength of the cervical flexor muscles in patients with TMD have been conducted. Thus, the present study was performed to add to the scarcity of knowledge in this area regarding the association between maximal cervical flexor muscle strength and the presence of temporomandibular disorders.

6.2 OBJECTIVES

1. The main objective of this study was to determine whether there was a difference in maximal cervical flexor muscle strength in subjects with TMD (mixed and myogenous TMD) when compared to healthy subjects.

   The secondary objectives of this study were:

2. To determine if there was an association between maximal cervical flexor muscle strength and jaw disability;
3. To determine if there was an association between maximal cervical flexor muscle strength and neck disability.

6.3 RESEARCH HYPOTHESES

1. Subjects with TMD (mixed and myogenous TMD) will have a reduced maximal cervical flexor strength when compared to healthy subjects.

2. There will be a strong association between maximal cervical flexor muscle strength and jaw disability.

3. There will be a strong association between maximal cervical flexor muscle strength and neck disability

6.4 METHODS

6.4.1 SUBJECTS

A convenience sample of subjects who attended the TMD/Orofacial Pain Clinic at the School of Dentistry, Faculty of Medicine and Dentistry, University of Alberta and healthy students and staff at the University of Alberta was recruited for this study using advertising in different faculties and surrounding areas of the University of Alberta (Appendix 1). Approximately 46 subjects per group were needed for this study. Sample size calculation for this study was based on multiple regression analysis using the guidelines proposed by Stevens (using α= 0.05, €= 0.05, population multiple correlation (ρ)=0.25).[32, 33]

The same inclusion/exclusion criteria for healthy as well as subjects with TMD described in Chapter 3 are applicable to this study

6.4.2 CLINICAL ASSESSMENT

Subjects underwent a clinical examination by an experienced physical therapist in musculoskeletal rehabilitation and treatment of temporomandibular disorders to determine if they met the inclusion criteria or were excluded by the exclusion criteria for this study. The clinical examination followed the guidelines of the diagnostic research criteria for TMD.[34] Briefly, all subjects were examined for pain in the masticatory muscles, the TMJ joint, and also the TMJ range of motion (appendices 2, 3, and 8).

If the physical therapist felt the subject did not meet the inclusion criteria, the subject was excluded of the study. Subjects were informed about the study and signed an informed consent in accordance with the University of Alberta's policies on research using human subjects (appendices 4 and 5)

6.4.3 INSTRUMENTATION AND PROCEDURES

6.4.3.1 General Considerations

Demographic data were collected on all subjects who satisfied the inclusion criteria including age, weight, and height. In addition, all subjects were asked to report specific characteristics regarding their jaw problem (i.e. onset, duration of symptoms, treatments received. All subjects were asked also to report their intensity of pain in the jaw (VAS), [35-39] and also complete the Neck Disability Index (NDI) (appendix 6), [40, 41] the Jaw Function Scale (LDF-TMDQ/JFS) (appendix 7),[42] and a history questionnaire for jaw pain used by the RDC/TMD (appendix 8).[34] These tools have been described previously in Chapter 3.

6.4.4 STRENGTH MEASUREMENT PROTOCOL

Before testing began, subjects were asked to perform a warm up, which consisted of two movements of the neck and head in all directions (flexion, extension, lateral inclination [right and left], and rotation [right and left]). The subjects were then placed in relaxed supine position with the knees flexed and the head and neck maintained in a mid-position. Thus, head and chin were parallel to the plinth. The evaluator made sure that subjects maintained the head and neck in this neutral position. Subjects were asked to position their arms over their chest in order to minimize contractions from the trunk muscles and limb muscles.[43]

After subjects were relaxed, they were asked to perform a submaximal isometric cervical flexion contraction (SMVC) (for 5 seconds), relax and to practice this task until they felt comfortable with the movement. The evaluator, a physical therapist with 14 years of experience in musculoskeletal rehabilitation, taught each subject how to do the movement and corrected any undesirable movement. Subjects were verbally encouraged to reach the highest level of activity in each trial. Once the tester was sure the subject had learned the procedure, each subject was asked to perform a maximal voluntary contraction (MVC) for the cervical flexor muscles. Subjects were asked to increase the strength over 1 sec, and to maintain that maximal strength for 5 seconds and relax afterwards. The 3 central seconds of this MVC plateau were used to calculate the maximal strength of the cervical flexor muscles. Each subject performed 2 repetitions of 5 seconds of this movement allowing 2 minutes between each trial to avoid fatigue. The average value of force of the 2 contractions registered was used as the MVC.

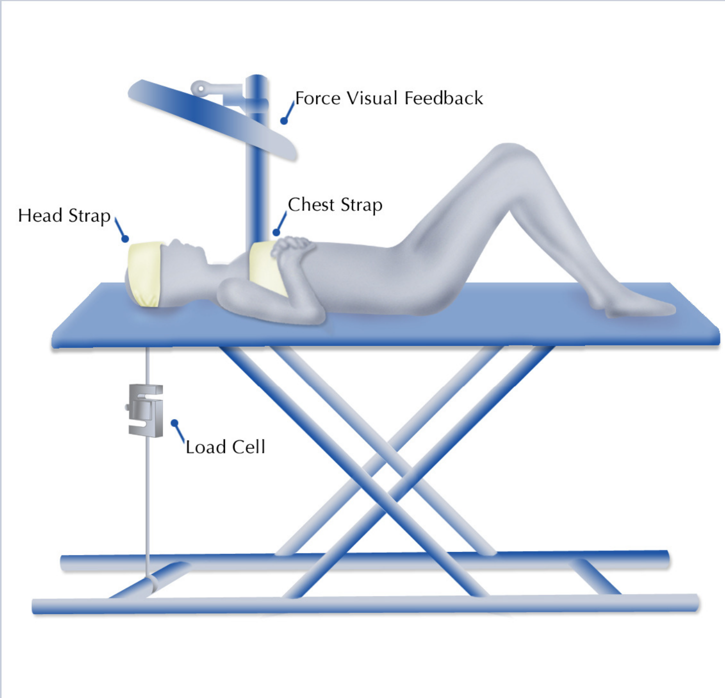

Figure 6-1. Set up for Measuring MVC of the Cervical Flexor Muscles

6.4.4.1 Instrumentation for Registering Force

A cervical flexion force device, attached to the plinth, was used to monitor the force that subjects perform during the cervical flexion movement. This device contained a load cell (Revere load cell; model: 9363-B10-500-20T1) to register the force generated by the subject during the procedure (Figure 6-1) (appendix 11). The load cell was calibrated with known weights obtaining a linear curve. The head of the subject was fixed with a strap which stabilized the head and served as a resistance to the cervical flexion movement.

The load cell signal was amplified and was connected with a visual feedback device using Igor software (http://www.wavemetrics.com/index.html).

Thus, each subject was provided with a feedback of the force level that she had reached during testing. Data was stored in the computer and analyzed offline.

Igor software was used to process the maximal strength for the flexor muscles. As mentioned above, the 3 central seconds of the MVC plateau graph saved in Igor software were used to calculate the maximal strength of the cervical flexor muscles. The data extraction was blinded to group status since each subject was coded by an external assistant.

6.5 ANALYSIS

The data of maximal cervical flexor strength were analyzed descriptively (i.e. mean, standard deviation). An ANCOVA analysis was used to analyze the differences in maximal flexor strength among groups when adjusted by body weight. ANCOVA analysis allowed us to compare the differences among groups having the baseline differences on body weight controlled. In addition, multiple regression analysis was used to analyze the association among jaw and neck disability with maximal cervical flexor strength. The values of the Jaw Function Scale (JFS) were categorized in order to use them in the multiple regression analysis (9-10 points: No disability; 11-24 points: moderate disability; ≥25 points: severe disability due to TMD). The level of significance was set at $\alpha = 0.05$. SPSS version 17 and STATA version 10 statistical programs were used to perform the statistical analyzed. Analysis was performed blinded to group condition.

6.6 RESULTS

6.6.1 SUBJECTS

A total number of 167 subjects were assessed for inclusion in this study. A total of 18 subjects were excluded. The main reasons for exclusion were: being not totally healthy (9 subjects), being older than 50 years old (2 subjects), having a neurological disease (1 subject), having cancer (1 subject), or the pain score was lower than 30 mm on the visual analogue scale (5 subjects).

One hundred and forty nine subjects provided data for this study. From these 149 subjects, 50 subjects were healthy, 54 subjects had myogenous Temporomandibular disorders (TMD) and 45 subjects had mixed TMD. Participants of this study were not engaged in strength training specifically targeted to the neck muscles. The general demographics for each group are as follows (Table 6-1):

Table 6-1. Descriptive Statistics of Height, Weight, and Age for all Subjects by Group (i.e. Myogenous TMD, Mixed TMD, and Healthy).

	Group	Mean	Std. Deviation	N
Height (cm)	Mixed TMD	166.02	6.11	45
	Healthy	165.26	6.64	50
	Myogenous TMD	164.99	5.11	54
Weight (kg)	Mixed TMD	71.61*	16.40	45
	Healthy	64.02†	12.35	50
	Myogenous TMD	64.11†	10.88	54
Age (years)	Mixed TMD	31.07	8.12	45
	Healthy	28.28	7.26	50
	Myogenous TMD	31.63	9.15	54

*** Significantly different when compared with healthy subjects at α=0.05**
† Significantly different when compared with subjects with mixed TMD at α=0.05

6.6.2 Sample Characteristics

There were no significant differences between groups for age and height. However, weight was significantly different between healthy subjects and subjects with mixed TMD (mean difference=7.59 kg [95%CI 1.0, 14.18] p=0.018) and between subjects with mixed TMD and subjects with myogenous TMD (mean difference =7.50 kg [95%CI 1.03, 13.97] p=0.017).

The descriptive data of the specific clinical characteristics of the subjects with TMD can be found in Table 6-2.

Table 6-2. Clinical Characteristics for all Subjects by Group (i.e. Myogenous TMD, Mixed TMD, and Healthy).

	Group	Mean	Std. Deviation	N
Duration of complaint (years)	**Mixed TMD**	**8.39***	**6.55**	45
	Healthy	**0.00**	**0.00**	50
	Myogenous TMD	**6.48***	**6.41**	54
Pain Intensity (mm)	**Mixed TMD**	**48.67***	**15.48**	45
	Healthy	**0.00**	**0.00**	50
	Myogenous TMD	**46.96***	**15.45**	54
Jaw Function Scale Score (points) 10 to 50	**Mixed TMD**	**22.36***	**7.001**	45
	Healthy	**10.16**	**0.472**	50
	Myogenous TMD	**18.87*†**	**6.088**	54
Neck Disability Index (points) 0-50	**Mixed TMD**	**12.38***	**6.23**	45
	Healthy	**1.72**	**1.68**	50
	Myogenous TMD	**10.76***	**5.83**	54

*** Significantly different when compared with healthy subjects at $\alpha=0.05$**
† Significantly different when compared with subjects with mixed TMD at $\alpha=0.05$

Regarding the clinical characteristics, subjects with TMD (mixed and myogenous) were evidently significantly different to healthy subjects in all the symptoms characteristics (pain intensity, duration of complaint, Neck Disability Index, and JFS) ($p<0.05$). Subjects with mixed TMD were similar to subjects with myogenous TMD in duration of complaint, pain intensity, and neck disability ($p>0.05$). Most of the patients had a long history of pain with an average of 8.39 years of pain for subjects with mixed TMD and 6.48 years for subjects with myogenous TMD. The average of pain intensity for patients with myogenous TMD was 46.96 mm and 48.67 mm for patients with mixed TMD.

Related to the level of disability of the subjects with TMD, both groups did not present with a high level of disability either in the neck or in the jaw. The maximum score for the Neck Disability Index is 50, and the subjects having mixed TMD only have an average of 12.38 points and the subjects with myogenous TMD had 10.76 points. Both values are considered only mild neck disability.[48, 50] Related to jaw function, subjects with mixed TMD obtained 22.36 points and subjects with myogenous TMD 18.87 points. Thus, the severity for both types of disability in this sample of patients was not severe.

Subjects with mixed TMD, were significantly different statistically in jaw disability ($p<0.05$) when compared to subjects with myogenous TMD. The mean difference score for JFS between subjects with mixed TMD and with myogenous TMD was 3.5 points ([95%CI 0.88, 6.09], $p=0.005$.

Although, neck disability scores were not statistically significantly different between subjects with mixed TMD and those with myogenous TMD, subjects with mixed TMD did present with a higher disability score than the subjects with myogenous TMD (12.38 vs. 10.76).

6.6.3 DIFFERENCE IN MAXIMAL CERVICAL FLEXOR MUSCLES STRENGTH BETWEEN SUBJECTS WITH TMD AND HEALTHY SUBJECTS

The descriptive data for maximal strength of the cervical flexor muscles for each group is displayed in Table 6-3 (adjusted by weight).

Table 6-3. Maximal Cervical Flexor Strength Estimates by Each Group.

Group	Mean (Newtons)	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Mixed TMD	25.92[a*]	2.26	21.45	30.38
Healthy	29.65[a*]	2.12	25.45	33.85
Myogenous TMD	25.20[a*]	2.04	21.16	29.24

a. Covariates appearing in the model are evaluated at the following values: Weight = 66.49.

***adjusted by body weight**
Values are expressed in Newtons

In general terms, a large variability in maximal strength was observed for all groups. The ANCOVA analysis used to test the mean differences in maximal cervical flexor muscle strength between TMD groups and healthy subjects demonstrated that there was no significant difference in maximal cervical flexor muscle strength among groups ($p>0.05$) when adjusted by body weight. Weight was significantly associated with maximal cervical flexor strength (Table 6-4). Neither age nor height were associated with maximal cervical flexor strength.

Table 6-4. ANCOVA Analysis Results. Test of Between Subjects Effects.

Dependent Variable: Maximal cervical flexor strength

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3903.74[a]	3	1301.25	5.83	0.001
Intercept	51.87	1	51.869	0.23	0.630
Group	573.67	2	286.83	1.29	0.279
Weight	3333.37	1	3333.37	14.95	0.000*
Error	32562.82	146	223.03		
Total	145032.20	150			
Corrected Total	36466.55	149			

*** Significant at α=0.05**

6.6.4 *ASSOCIATION BETWEEN MAXIMAL CERVICAL FLEXOR MUSCLE STRENGTH AND JAW DISABILITY*

When evaluating the relationship among maximal strength of the cervical flexor muscles, neck disability, and jaw disability, it was found that there was no significant association between maximal strength of the cervical flexor muscles and jaw disability at any severity category after adjusting for age, height and weight ($F(5, 144) = 3.49$;$p = 0.0052$, R-squared = 0.11) (Table 6-5).

Table 6-5. Multiple Regression Analysis between Maximal Strength of the Cervical Flexor Muscles and Jaw Disability Measured Through the Jaw Function Scale.

Max Strength	Coefficient	Std. Error	t	P>|t|	[95% Confidence Interval]	
Moderate Disability	-2.33	2.74	-0.85	0.396	-7.75	3.08
Severe Disability	-4.48	4.08	-1.10	0.274	-12.55	3.58
Height	-0.18	0.23	-0.80	0.427	-0.64	0.27
Weight	0.41	0.10	3.96	0.00*	0.20	0.61
Age	-0.11	0.15	-0.72	0.47	-0.41	0.19
constant	35.73	36.45	12.89	0.329	-36.32	107.78

Max strength: Maximal Strength of the Cervical Flexor Muscles
JFS: Jaw Function Scale
*** Significant at α=0.05**

6.6.5 *ASSOCIATION BETWEEN MAXIMAL CERVICAL FLEXOR MUSCLE STRENGTH AND NECK DISABILITY*

A significant but weak association between neck disability and maximal strength of the cervical flexors muscles was found after adjusting for age, height, and weight ($F(4, 144) = 6.01$; $p= 0.0002$;R-squared = 0.14); ($\beta=-0.1$, $t=-2.79$ $p=0.006$; 95%CI-0.17 -0.028) (Table 6-6).

Table 6-6. Multiple Regression Analysis. Relationship between Maximal Strength of the Cervical Flexor Muscles and the Neck Disability Measured through the NDI, adjusted by Weight, Height and Age.

NDI	Coefficient	Std. Error	t	P>|t|	[95% Confidence Interval]	
Max Strength	**-0.1**	**0.03**	**-2.79**	**0.006***	**-0.17**	-0.03
Weight	**0.14**	**0 .05**	**3.01**	**0.003***	**0.05**	0.23
Height	**-0.08**	**0.09**	**-0.78**	**0.438**	**-0.27**	0.12
Age	**0.17**	**0 .06**	**2.68**	**0.008***	**0.05**	0 .30
constant	9.25	15.53	0.60	0.552	-21.45	39.95

NDI: Neck Disability Index
Max strength: Maximal Strength of the Cervical Flexor Muscles
*** Significant at α=0.05**

6.7 DISCUSSION

The main objective of this study was to determine whether there was a difference in maximal cervical flexor muscle strength in subjects with TMD (mixed and myogenous TMD) when compared to healthy subjects. According to the results of this study, there was no significant association between maximal strength of the cervical flexor muscles and presence/absence of TMD. It was found that subjects with mixed TMD and myogenous TMD did not have significantly different maximal flexor muscle strength when compared with healthy subjects when adjusted by body weight. These results do not support the first hypothesis of this study. The results of this study cannot be compared with other studies investigating the same variables and groups because there was a lack of literature on this topic and this population. No study was found that investigated the strength of the cervical muscles in patients with TMD. By looking at this topic in this group of subjects, this study contributes to the body of knowledge in this area.

The results of this study, however, can be compared with other studies investigating the strength of cervical flexor muscles in other musculoskeletal painful conditions such as neck pain, whiplash associated disorders (WAD) and cervicogenic headache. According to a recent systematic review [44] investigating cervical impairments in chronic neck pain, it was found that cervical strength was decreased in patients with neck disorders such as neck pain and WAD when compared to control subjects. All of the analyzed studies [22, 45-50] found that either the extensor and/or flexor cervical muscles [45-50] or the craniocervical flexor muscles [22] were impaired in strength in subjects with neck pain. Regarding the studies investigating the strength in the flexor cervical muscles, six [22, 45, 47-50] out of seven found significantly lower strength in the cervical flexors muscles in patients with cervical disorders when compared with asymptomatic subjects. In addition, another systematic review studying the strength of the cervical muscles in individuals with cervicogenic headache [30] found similar results. The two studies [51, 52] investigating cervical strength of the flexor muscles in patients with cervicogenic headaches had lower values when compared to healthy subjects. Thus, it seems that painful neck conditions present with lower cervical flexor muscle strength. However, it has to be acknowledged that all of these studies are cross sectional in nature and thus, a cause and effect relationship cannot be established. It remains unclear and it has been a matter of recent study [53] whether muscles weakness is the cause or effect of musculoskeletal pain. Future studies investigating musculoskeletal pain should look at this issue.

The results of this study showed that no significant differences among groups in maximal strength were found. One possible explanation for these results could be the level of disability presented by the subjects with TMD. When comparing the levels of neck disability of these subjects with the other studies investigating strength,[22, 50] it was found that the level of disability, not only at the level of the neck but also at the level of the jaw, was considered mild for subjects with TMD. Thus, the severity of disability could have an influence on muscular performance of the cervical flexor muscles. Furthermore, it has been suggested by other researchers,[20, 54] that chronic pain is likely to affect the rapid production of force rather than affecting the maximal strength. This could be the result of fear on the part of patients to increasing pain during rapid movements. In addition, it has been pointed out that patients with chronic pain have an altered pattern of muscle contraction rather than an alteration of maximal effort.[20] Future studies looking at this question would be important to clarify whether patients with TMD have impaired rapid force capacity or less adaptability to respond to reflex conditions than healthy subjects.

According to a review performed by Dvir and Prsushansky,[23] there is a great deal of variability in the strength values provided by the different studies. They showed that the cervical strength for women in flexion and extension varied between 20 to 100 N and 40 to 180 N respectively. The same tendency occurred for men. In addition, this variability did not improve when torque measurements (Nm) were considered. The range of the values for women was between 11 to 116 Nm for flexion and between 22 to 139 Nm for extension. The variability in cervical strength measurements can be explained by the wide variety of protocols and systems used to measure strength (e.g. manual muscle testing, handheld dynamometers, fixed frame dynamometry, and isokinetic measuresments) and also by the between subject variability in terms of weight, size and volume of the head, among others. Thus, the results obtained for this study are difficult to compare specifically to values obtained by the other studies. This study used a supine position, a dynamometric evaluation (using a load cell), and isometric contractions. This type of evaluation had been conventionally used in the clinically setting to determine impairments in strength. Thus this study tried to imitate as close as possible the clinical situation. In addition, this method was chosen to measure strength of cervical flexors isometrically since, physiologically, the cervical muscles function is to stabilize the neck and give support to the head which is primarily an isometric function.[55]

Regarding the relationship between strength of the cervical flexor muscles and level of disability of the neck measured through the Neck Disability Index (NDI) and the level of jaw disability measured through the Jaw Function Scale (JFS), no significant association was found between maximal cervical flexor muscle strength and jaw disability. Thus, these results do not support the second hypothesis of this study. A weak association was found between NDI and maximal strength of the cervical flexors muscles rejecting the third hypothesis of this study. No other studies investigating the association between neck flexors strength and jaw disability were found. However, the association between neck disability and maximal strength has been studied in subjects with WAD and neck pain.[56-58] These studies found that maximal strength was not associated with neck disability. The results of this study are in agreement with the findings of the referenced studies.[56-58] These results could indicate that maximal strength cannot be considered as a direct measure of disability. Disability and function are complex constructs that depend on multiple factors. These factors could be physical but also could be psychological. It has been suggested that pain-related beliefs such as self-efficacy are important determinants of disability.[59] Thus, strength assessment is only one of the more physical impairments that need to be addressed when evaluating musculoskeletal painful conditions such as TMD and neck pain. Strength evaluation is important for clinicians, since, as reported by Ylinen et al.,[58], maximal strength describes the patients' ability to "tolerate strain", specially the neck flexor muscles, which may become strained more easily than the extensor muscles due to their biomechanical action.[60]

Furthermore, because of the great variability of strength measurement in the neck, patients cannot be differentiated from healthy subjects since normal values are still not available, unless that those subjects were tested in the same system under the same protocol.[23] However, studies that have investigated strength in the neck have pointed out that commonly patients with neck disorders have impaired cervical strength when compared with healthy subjects. Thus this knowledge is important since strength testing can be used by the clinicians to test the basic strength for each patient, setting goals for treatments and determine improvement after treatment implementation.[50]

Commonly, physical therapy treatments for people with TMD include exercises focused on the cervical spine. [61, 62] However, these treatments are based mostly on empirical information.[1] The results of a recent systematic review investigating physical therapy interventions to treat TMD indicated that neck exercises used to treat posture in patients with TMD lacked a clear exercise prescription (i.e. type of exercise, dosage, and frequency) as well as a clear underlying mechanism of why these exercises, directed toward to the neck, improved TMD symptoms. Thus, research investigating cervical muscle impairments in patients with TMD could help clarifying which exercises would be beneficial for these patients. In order to guide treatment decisions, researchers need to determine and understand the dysfunctions that are present in individuals with TMD. Thus, this study contributes to knowledge regarding the cervical impairments in this population and the use of this information when evaluating and treating patients with TMD. Although the results of this study highlight that maximal isometric cervical flexor strength was not altered in patients with TMD, it is still unknown if other muscular groups such as cervical extensors, rotators or lateral inclinators have reduced isometric maximal strength in these patients. In addition, it is unknown if strength measured under different conditions such as rapid movements or considering patients with more severe jaw disability would be affected. Future research should look into these issues and clarify the role of maximal strength of cervical muscles in these groups of patients. Knowing which cervical muscular impairments could be present in subjects with TMD, would enable clinicians to focus on those impairments and plan more effective treatments.

6.8 CONCLUSION

Maximal strength of the cervical flexor muscles was found to be not significantly different among patients with mixed TMD, myogenous TMD and healthy subjects. No significant association between jaw disability with maximal neck flexor muscle strength was found. A significant but weak association between neck disability and maximal neck flexors muscle strength was found. These results indicated that strength assessment is one of more physical impairments that need to be addressed when evaluating musculoskeletal painful conditions such as TMD and neck disorders but cannot be considered as a direct measure of disability. Future studies should explore evaluation of strength in other muscular groups such as extensors, rotators and lateral inclinators and also under different condition such as rapid movements and in patients with more severe jaw disability.

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7 CHAPTER 7

ENDURANCE OF THE CERVICAL FLEXOR MUSCLES IN PATIENTS WITH TEMPOROMANDIBULAR DISORDERS

7.1 INTRODUCTION

Endurance or “resistance to fatigue” is one of the main properties of skeletal muscles. Endurance has been defined in a broad sense as: “the ability to perform low intensity, repetitive, or sustained activities over a prolonged period of time” (p.60).[1] In addition, the concept of local fatigue can be understood as “the ability of a muscle to contract repeatedly against a load (resistance), generate and sustain tension, and resist fatigue over an extended period of time”.[1](p.60) Muscle endurance has been acknowledged as a key factor allowing spinal muscles to maintain the stability of the spinal system.[2] Human beings require not only strong muscles but also muscles able to tolerate loads and be active for long periods of time to maintain proper function. Neck muscles have to stabilize the head and neck to maintain posture and resist perturbations. The cervical muscles also distribute loads to bones (e.g. vertebre, and skull) and connective tissues. All of these activities make them complex structures with multiple tasks for maintaining the normal functioning of the cervical spinal system. Since cervical muscles’ role is to maintain stability while allowing mobility of the neck, endurance capacity has been commonly considered in the evaluation of the physical functioning of the cervical spine.

One of the most frequent musculoskeletal impairments found in the cervical region is cervical muscular dysfunction.[3, 4] Deep flexor muscles including longus colli and longus capitis as well as superficial cervical flexors muscles such as the sternocleidomastoid (SCM), the scalenes, and supra- and infrahyoid muscles are important for cervical segmental and postural control and movement respectively. Alterations in motor control, performance, strength and endurance of the cervical flexor and extensor muscles has been stated to be present in patients with neck pain and patients with cervical dysfunction. It seems that deep and superficial cervical flexor and extensor muscle impairment is a common factor in patients with cervical involvement such as neck pain, whiplash disorders (WAD), and cervicogenic headache (CEH).[3, 5, 6] Subjects with temporomandibular disorders (TMD) have been found to have clinical signs and symptoms of cervical dysfunction [7-14]. This association between TMD and cervical spine dysfunction is supported by the anatomical, biomechanical and neurophysiological interactions between the two systems [15-17]: the stomatognathic system and craniocervical system.

Although many studies have investigated the relationship between the cervical spine and craniofacial pain including TMD, [7, 9, 10, 18-32] no study was found that evaluated the endurance capacity of the cervical muscles in patients with TMD. As stated previously, endurance capacity is one of the key elements for proper cervical muscle function. Theoretically, when the cervical flexor muscles lose endurance and their performance is impaired, the balance between the extensor and flexor cervical muscles will be interrupted and as a result improper posture and alignment could lead to cervical dysfunction.[33]

The evaluation of endurance is of clinical importance since values of holding time have been used as outcome parameters to determine muscular impairment and change/improvement of a condition during treatment. In addition, improvements in endurance have been connected with improvements in function and symptoms.[34, 35]

Thus, the present study was performed to increase the body of knowledge regarding the association between endurance of the cervical flexor muscles and the presence of temporomandibular disorders.

7.2 OBJECTIVES

1. The main objective of this study was to determine whether patients with TMD (myogenous and mixed TMD) had a reduced endurance (measured through the holding time -in seconds-) of the cervical flexor muscles at different levels of muscular contraction (25%, 50%, and 75% Maximum Voluntary Contraction) when compared to healthy subjects. The secondary objectives of this study were:

2. To determine if the maintained strength of the cervical flexor muscles was reduced during the endurance test in patients with TMD disorders (myogenous and mixed TMD) at any level of muscular contraction (25%, 50%, and 75% MVC) when compared to healthy subjects.

3. To determine if there was an association between endurance of the cervical flexor muscles and neck disability.

4. To determine if there was an association between endurance of the cervical flexor muscles and jaw dysfunction/disability.

5. To determine if there was an association between level of chronic disability of TMD based on the RDC/TMD (Chronic Pain Grade), pain intensity, duration of complaint, and interference with activities of daily living using the RDC/TMD scales and the endurance and maintained strength of the cervical flexor muscles.

7.3 RESEARCH HYPOTHESES

The following hypotheses were investigated in this study:

1. Patients with TMD (myogenous and mixed TMD) will have a reduced endurance (measured through the holding time [in seconds]) of the cervical flexor muscles at different levels of muscular contraction (25%, 50%, and 75% Maximum Voluntary Contraction) when compared to healthy subjects.

2. Patients with TMD disorders (myogenous and mixed TMD) will have a different averaged maintained strength of the cervical flexor muscles during the endurance test at any level of muscular contraction (25%, 50%, and 75% MVC) when compared to healthy subjects.

3. There will be a strong association between endurance of the cervical flexor muscles and neck disability;

4. There will be a strong association between endurance of the cervical flexor muscles and jaw dysfunction/disability.

5. There will be a strong association between level of chronic disability of TMD based on the RDC/TMD (Chronic Pain Grade), pain intensity, duration of complaint, and interference with activities of daily living using the RDC/TMD scales and the endurance and maintained strength of the cervical flexor muscles.

7.4 METHODS

7.4.1 SUBJECTS

A convenience sample of subjects who attended the TMD/Orofacial Pain Clinic at the School of Dentistry, Faculty of Medicine and Dentistry, University of Alberta and healthy students and staff at the University of Alberta was recruited for this study using advertising in different faculties and surrounding areas of the University of Alberta (Appendix 1). Sample size calculation for this study was based on multivariate analysis of variance with two dependent variables and 3 groups using the guidelines proposed by Stevens (using α= 0.05, β= 0.20, power = 80%, and a moderate effect size).[36] Approximately, a number of 44 subjects were needed per each group. Subjects were continually recruited until the total sample was obtained.

The same inclusion/exclusion criteria for healthy as well as subjects with TMD described in Chapter 3 are applicable to this study

7.4.2 CLINICAL ASSESSMENT

Subjects underwent a clinical examination by a physical therapist with experience in musculoskeletal rehabilitation and treatment of temporomandibular disorders (principal investigator) to determine if they met the inclusion criteria or were excluded by the exclusion criteria for this study. The clinical examination followed the guidelines of the diagnostic research criteria for TMD.[37] Briefly, all subjects were examined for pain in the masticatory muscles, the TMJ joint, and also the TMJ range of motion (Appendices 2 and 3)

If the physical therapist felt the subject did not meet the inclusion criteria, the subject was excluded of the study. Subjects were asked to read an information letter (appendix 4) and signed an informed consent in accordance with the University of Alberta's policies on research using human subjects (appendix 5).

7.4.3 INSTRUMENTATION AND PROCEDURES

7.4.3.1 General Considerations

Demographic data were collected on all subjects who satisfied the inclusion criteria including age, weight, and height. In addition, all subjects were asked to report specific characteristics regarding their jaw problem (i.e. onset, duration of symptoms, treatments received). All subjects were asked also to report their intensity of pain in the jaw (VAS), [38-42] and also complete the Neck Disability Index (NDI) (appendix 6), [43, 44] the Jaw Function Scale (LDF-

TMDQ/JFS) (appendix 7),[45] and a history questionnaire for jaw pain used by the RDC/TMD (appendix 8).[37] In addition, the subjects were asked to complete the Chronic Pain Grade Disability Questionnaire for TMD used by the RDC/TMD to evaluate the level of chronic disability due to TMD (appendix 9).[37] These tools have been described previously in Chapter 3.

7.4.3.2 Procedure for Evaluating Cervical Flexor Muscles Endurance

Before testing started, subjects were asked to perform a warm up, which consisted of two movements of the neck and head in all directions (flexion, extension, lateral inclination, and rotation). The subjects were then placed in relaxed supine position with the knees flexed and the head and neck maintained in a mid-position attached to a head strap. Thus, head and chin were parallel to the plinth. The evaluator made sure that subjects maintained the head and neck in neutral position. Subjects were asked to position their arms over their chest in order to minimize contractions from the trunk muscles and limb muscles.

After the subjects were relaxed, they were asked to perform a maximal isometric cervical flexion contraction (MVC) (for 5 seconds) retracting their chin and lifting their head from the plinth as allowed by the load cell registration system, to relax and to practice the action until they feel comfortable with it. The evaluator taught each subject how to do the movement and corrected any undesirable movement. Subjects were verbally encouraged to reach the highest level of activity in this trial of MVC. Once the tester had ensured that the subject had learned the procedure, each subject was asked to perform the maximal voluntary isometric contraction (MVC). Each subject performed 2 repetitions of this movement allowing 5 minutes between each trial to avoid fatigue. The average force value of the 2 contractions registered was used as the reference MVC. This allowed submaximal target contractions (i.e. percentage MVC) to be set on the visual feedback display related to this value.

After performing the MVC, and when the tester had ensured that the subject had learned the procedure for doing submaximal contractions with the help of the visual biofeedback, each subject was asked to perform 2 submaximal cervical flexion contractions at 25% MVC, 50% MVC, and 75% MVC, keeping the chin retracted, and maintain these contractions as long as possible using a visual display for feedback of the force output (Figure 7-1). The subjects were asked to do their best and breathe normally during the test. In addition, subjects were told that they could stop the test at any time. The test was stopped when 1) the subject could not maintain the desired target strength level (i.e. percentage MVC) determined for the test, 2) the subject complained of an unacceptable level of discomfort. The time of contraction and the maintained strength during each level of contraction were registered and saved it in a computer using Igor software. The order of the MVC levels (25%, 50%, and 75% MVC) was randomized by an independent assessor before each subject's test. Five minutes of rest was allowed for all trials. Each subject was verbally encouraged to maintain the position as long as possible.

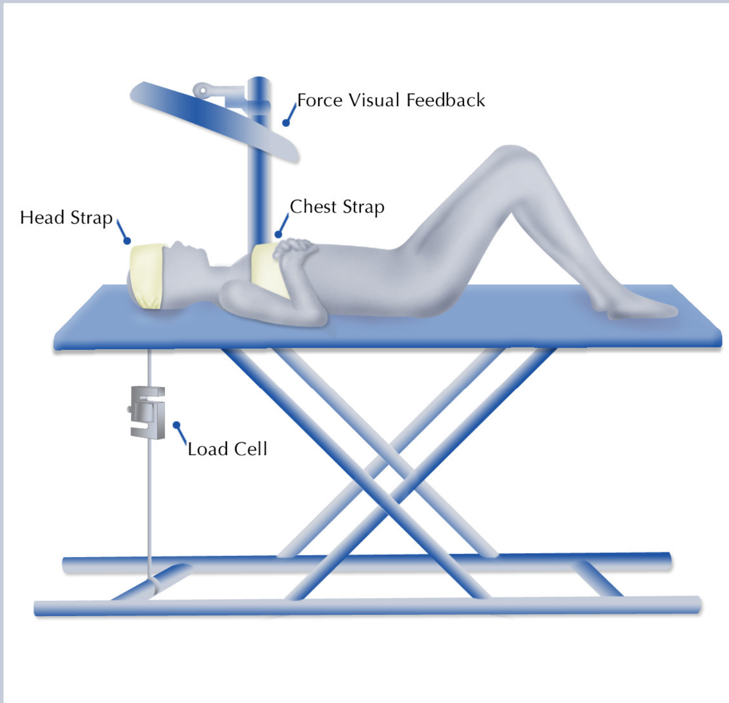

Figure 7-1. Set up for Measuring Endurance of the Cervical Flexor Muscles

7.4.3.3 Instrumentation for Registering Force

A cervical flexion force device, attached to the plinth, was used to monitor the force that subjects performed during the cervical flexion movement. This device contained a load cell (Revere load cell; model: 9363-B10-500-20T1) to register the force generated by the subject during the procedure (Figure 7-1) (appendix 11). The load cell was calibrated with known weights obtaining a linear curve. The head of the subject was fixed with a strap which stabilized the head and served as a resistance to the cervical flexion movement.

The load cell signal was amplified and was connected with a visual feedback device using Igor software (http://www.wavemetrics.com/index.html).

Thus, each subject was provided with feedback of the force level (i.e. percentage MVC) that she had to reach and maintain during the trials.

The time of contraction and the maintained strength during each level of contraction were registered and saved in a computer using Igor software and were analyzed offline by a blinded evaluator. The average of the two repetitions was used for analysis.

7.5 ANALYSIS

The data of maintained cervical flexor strength (Newtons) and flexor muscle endurance (holding time -seconds-) were analyzed descriptively (i.e. mean, standard deviation). A repeated measure MANCOVA test was used to analyze the difference between holding time (sec) and strength maintained (Newtons) obtained at different levels of contraction among groups adjusted by body weight. Paired comparisons using Bonferroni Post hoc test were used to evaluate the differences between endurance and strength at different conditions (objectives 1 and 2). The level of significance was set at $\alpha = 0.05$. Spearman rho test was used to evaluate the relationship of the Neck Disability Index, Jaw Function Scale, and clinical variables such as the level of chronic disability of TMD based on the RDC/TMD (Chronic Pain Grade Questionnaire), pain intensity, duration of complaint, and interference with activities of daily living using the RDC/TMD scales to endurance and maintained strength variables (correlational matrix) (objectives 3, 4, and 5). The correlation was considered important when the correlation coefficient value was higher than 0.70. The reference values to make this decision were based on values reported by Munro[54].

SPSS version 17 and STATA version 10 statistical programs were used to perform the statistical analysis. The person doing the analysis was blinded to group condition.

7.6 RESULTS

7.6.1 SUBJECTS

A total number of 169 subjects were assessed for inclusion in this study. A total of 20 subjects were excluded. The main reasons for exclusion were: being not totally healthy (9 subjects), being older than 50 years old (2 subjects), having a neurological disease (1 subject), having cancer (1 subject), or the pain score was lower than 30 mm on the visual analogue scale (5 subjects). Two subjects with mixed TMD could not complete the test because of the presence of unacceptable pain. One hundred and forty nine participants (149) provided data for this study. From these 149 subjects, 49 subjects were healthy, 54 subjects had myogenous temporomandibular disorders (TMD) and 46 subjects had mixed TMD.

The general demographics for each group are as follows (Table 7-1)

Table 7-1. Descriptive Statistics of Height, Weight, and Age for all Subjects by Group (i.e. Myogenous TMD, Mixed TMD, and Healthy).

	Group	Mean	Std. Deviation	N
Height (cm)	**Mixed TMD**	**166.04**	**6.04**	46
	Healthy	**165.22**	**6.71**	49
	Myogenous TMD	**164.99**	**5.11**	54
Weight (kg)	**Mixed TMD**	**72.05***	**16.35**	46
	Healthy	**64.15†**	**12.44**	49
	Myogenous TMD	**64.10†**	**10.88**	54
age (years)	**Mixed TMD**	**31.02**	**8.04**	46
	Healthy	**28.35**	**7.32**	49
	Myogenous TMD	31.63	9.15	54

*** Significantly different when compared with healthy subjects at α=0.05**
† Significantly different when compared with subjects with mixed TMD at α=0.05

7.6.2 Sample Characteristics

All subjects were comparable in age and height. No significant differences were found among groups in these variables. Weight was significantly different among groups ($p<0.05$). Subjects with mixed TMD had higher weight than healthy subjects and subjects with myogenous TMD (mean difference with healthy subjects: 7.9 kg [95%CI 1.294, 14.498], p=0.013; mean difference with subjects with myogenous TMD=7.95 kg [95%CI 1.492, 14.397], p=0.010).

The descriptive data of the specific characteristics of the subjects with TMD can be found in Table 7-2.

Table 7-2. Clinical Characteristics for all Subjects by Group (i.e. Myogenous TMD, Mixed TMD, and Healthy).

	Group	Mean	Std. Deviation	N
Jaw Function Scale (points) 10-50	**Mixed TMD**	**22.53***	**7.29**	45
	Healthy	**10.12**	**0.39**	49
	Myogenous TMD	**19.00*†**	**6.20**	54
Neck Disability Index (NDI) (points) 0-50	**Mixed TMD**	**12.38***	**6.23**	45
	Healthy	**1.71**	**1.59**	49
	Myogenous TMD	**10.76***	**5.83**	54
Duration of complaint (years)	**Mixed TMD**	**8.01***	**6.36**	46
	Healthy	**0.00**	**0.00**	49
	Myogenous TMD	**6.53***	**6.65**	54
Pain Intensity (0-100 mm) (VAS)	**Mixed TMD**	**48.26***	**15.55**	46
	Healthy	**0.00**	**0.00**	49
	Myogenous TMD	46.00*	16.42	54

*** Significantly different when compared with healthy subjects at α=0.05**
† Significantly different when compared with subjects with mixed TMD at α=0.05

Subjects with TMD (myogenous and mixed TMD) were significantly different in all clinical variables (i.e. pain intensity, duration of complaint, Neck Disability Index, and Jaw Function Scale) than healthy subjects. Subjects with TMD (myogenous and mixed TMD) were similar in most of the clinical variables (duration of complaint, pain intensity, and Neck Disability Index). The average pain intensity for patients with myogenous TMD was 46 mm and 48.3 mm for patients with mixed TMD. This level of pain is considered moderate.[40] Most of the patients had a long history of pain with an average of 8 years for subjects with mixed TMD and 6.5 years for subjects with myogenous TMD.

The jaw disability measured with the Jaw Function Scale (LDF-TMDQ or JFS)[52] was significantly different between subjects with mixed TMD and subjects with myogenous TMD (mean difference= 3.53 points, [95%CI 0.84, 6.22] p=0.005). The Neck Disability Index was not significantly different statistically between TMD groups, although the neck disability scores were higher for subjects with mixed TMD than subjects with myogenous TMD (12.38 points for subjects with mixed TMD and 10.76 points for subjects with myogenous TMD).

Regarding the level of disability of the two groups with TMD, it was found that both groups had a mild level of disability in the jaw as well as the neck. The maximum score for the Neck Disability Index is 50, and the subjects having mixed TMD only had 12.4 points and the subjects with myogenous TMD had 10.76. Both values were considered only mild neck disability. Related to the Jaw Function Scale, the maximum score was 50 points and the average obtained by the subjects with TMD was 22.5 points for subjects with mixed TMD and only 19 points for subjects with myogenous TMD. Thus, based on these two scales, the severity for both types of disability in this sample of patients was not severe.

7.6.3 CERVICAL FLEXOR ENDURANCE AND MAINTAINED STRENGTH

The descriptive estimates for maintained time and maintained strength among groups when adjusted by weight can be found in Table 7-3.

Table 7-3. Descriptive Estimates for Maintained Time and Maintained Strength among Groups when Adjusted by Body Weight.

Measure	Group	Contraction level	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Maintained Time (seconds)	Mixed TMD	25% MVC	20.55[a] * †	1.77	17.05	24.05
		50% MVC	17.55[a]	1.73	14.13	20.97
		75% MVC	12.31[a]	1.27	9.780	14.83
	Healthy	25% MVC	28.06[a]	1.68	24.74	31.38
		50% MVC	18.74[a]	1.64	15.49	21.99
		75% MVC	14.40[a]	1.21	12.01	16.79
	Myogenous TMD	25% MVC	27.33[a]	1.60	24.17	30.50
		50% MVC	20.72[a]	1.57	17.63	23.82
		75% MVC	14.42[a]	1.15	12.14	16.69
Maintained Strength (Newtons)	Mixed TMD	25% MVC	6.70[a]	0.60	5.52	7.87
		50% MVC	12.94[a]	1.17	10.64	15.25
		75% MVC	18.68[a]	1.65	15.42	21.94
	Healthy	25% MVC	7.66[a]	0 .56	6.55	8.78
		50% MVC	14.40[a]	1.11	12.22	16.59
		75% MVC	20.16[a]	1.57	17.07	23.26
	Myogenous TMD	25% MVC	6.53[a]	0.54	5.47	7.59
		50% MVC	12.87[a]	1.06	10.78	14.95
		75% MVC	18.27[a]	1.49	15.32	21.21

a. Covariates appearing in the model are evaluated at the following values: Weight = 66.57.

*** Significantly different when compared with healthy subjects at α=0.05**
† Significantly different when compared with subjects with myogenous TMD at α=0.05

The 2-way mixed repeated measure MANCOVA determined that there were statistically significant differences in holding time (sec) among groups (Greenhouse-Geisser F=3.31, p=0.013). However, there were no significant differences in maintained strength (Newtons) among groups (Greenhouse-Geisser F= 3.879, p=0.875). The pair wise comparisons using Bonferroni post hoc tests determined that there was a significantly reduced endurance hold time at 25% of the MVC in subjects with mixed TMD when compared to healthy subjects and subjects with myogenous TMD (mean difference with healthy= -7.51 seconds, [95%CI -13.492, -1.527], p=0.008; mean difference with myogenous TMD= -6.78 seconds, [95%CI -12.639, -0.926], p=0.017). The remaining levels of contraction did not show significant differences in endurance hold time.

7.6.4 Association between Endurance, Maintained Strength and Clinical variables

Related to the associations between endurance holding time, maintained strength during the test and clinical variables such as pain intensity, duration of complaint, neck disability, jaw disability, level of chronic disability of TMD (Chronic Pain Grade Disability questionnaire), and pain interference with ADL, only very weak correlations were found. In other words, no significant associations between clinical variables and performance variables such as endurance (holding time) and maintained strength were found (Table 7-4).

Table 7-4. Correlations between Holding Time, Maintained Strength, and Clinical Data.

Variable	Time of complaint (years)	Pain Intensity (VAS)	Chronic Pain Grade Class.	Jaw Function Scale (JFS)	Interference with ADL (RDC/TMD)	Neck Disability Index (NDI)
25% MVC Holding time	-0.002	-0.022	-0.111	-0.130	-0.081	-0.155
50% MVC Holding time	0.107	0.171*	0.042	0.091	0.021	0.054
75% MVC Holding time	-0.028	0.030	-0.005	-0.010	0.005	-0.092
25% MVC Maintained Strength	-0.021	-0.146	-0.171	-0.170*	-0.208*	-0.226**
50% MVC Maintained Strength	0.007	-0.124	-0.145	-0.146	-0.181*	-0.203*
75% MVC Maintained Strength	0.027	-0.102	-0.122	-0.140	-0.177*	-0.189*

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

7.7 DISCUSSION

This study provides evidence regarding the endurance capacity of patients with temporomandibular disorders when compared to healthy subjects. The main finding of this study was that there was a statistically significant difference in endurance holding time at 25% MVC between subjects with mixed TMD when compared to subjects with myogenous TMD and healthy subjects. Thus, the results partially support the first hypothesis of this study for only one perecentage of MVC (i.e. 25%). This result is of importance for clinicians who work with subjects with temporomandibular disorders since the assessment of the endurance of the cervical flexor muscles in patients with TMD could help with the planning of physical therapy treatment in these patients. Treatment focused on improving the endurance of the cervical flexor muscles may improve function of the neck. This could potentially have an effect on the functioning of the craniomandibular system and as a result, could contribute to decreasing the load on the system and potentially reduce the symptoms associated with it.

The results of this study cannot be directly compared with other studies investigating the same variables in patients with TMD because of the lack of information in the literature investigating neck endurance in this population. No study was found which investigated the endurance (evaluated through the holding time) of the cervical muscles in patients with TMD. Consequently, this study significantly contributes, to increase the knowledge in this area.

The results of this study, however, can be compared with other studies investigating the endurance of cervical flexor muscles in healthy subjects [47-50] and other painful musculoskeletal conditions such as neck pain, [33, 51-56] whiplash associated disorders (WAD)[57] and cervicogenic headache [58-60] which are cervical related disorders.

In general terms, the endurance evaluation has been performed using different type of tests. Nevertheless, the clinical tests, as used in clinical practice, will be discussed in this section since they are similar to the test performed in the present study. The endurance tests used commonly in clinical research varied according to the position used and the type of muscles involved in the test. Most of the studies investigating endurance tests tried to address the endurance only of the upper cervical flexor muscles [33, 47-56, 58-60] and one study used a more global evaluation of the total cervical flexor muscles [57]. Even though researchers try to focus on the upper cervical flexors muscles, asking the subjects to retract their chin, the test involves work of all the cervical flexor muscles as a group since the long superficial cervical flexor muscles also contribute to maintain this position.[61] Conley et al.,[61] found that the largest contribution for flexion cervical movement was performed by the sternocleidomastoid (SCM) muscles. The longus capitis/colli muscles also showed high activity during the cervical flexion movement [61]. In addition, Moroney et al.,[62] showed that the infrahyoid muscles and scalenes were also important components of the cervical flexion movement. Muscles involved in cervical flexion, in order of intensity of action (from EMG analysis) are: SCM, longus colli, longus capitis, suprahyoid (i.e the stylohyoid, mylohyoid, genihyoid and digastric muscles), infrahyoid [i.e. the omohyoid (which bridges scapula with the hyoid bone), and the sternohyoid (which connects the sternum and clavicle with the hyoid bone], rectus capitis anterior, and the scalene muscles [63]. Thus, it is difficult to separate the involvement of a specific group of muscles such as the upper cervical flexor muscles since flexion movement is a compound movement and therefore should be considered as a general test of endurance of the cervical flexor muscles.

When comparing this present study to other studies in different populations, it was realized that many protocols and ways of evaluating endurance of the neck flexors muscles have been used. The most common way to evaluate the endurance of the cervical flexor muscles was described by Grimmer in 1994. [49] Since then, many modifications have been used, providing different values of holding time according to the setting and population investigated. From the studies looking into healthy subjects, the values of holding time ranged from 14.5 seconds [49] to 118.9 seconds.[57] For example Grimmer [49] reported values of 14.5 seconds (sd=4.3) for healthy women and 18.2 seconds (sd=3.3) for healthy men. Dumas et al., [58] also found similar results for healthy subjects in a sample of women and men obtaining 18.9±7.7 seconds. However, other studies such as the ones by Kumbhare et al.,[57]Watson [59] and Watson and Trott [60] found higher holding times for their sample of healthy subjects. Kumbhare et al.,[57] reported an average of 118.9 seconds for a mixed sample (women and men) and Watson [59] and Watson and Trott [60] reported an average of 84.90 seconds for females only. The results of the present study regarding holding time for healthy subjects are within the range found in other studies. The holding time for the present study was between 28.1 seconds (25%MVC) and 14.4 seconds (75%MVC). However, none of the studies found evaluated holding time using different percentages of the maximal voluntary contraction which limits a direct comparison of these results. Previous studies just asked the subjects to raise their head without a specific percentage of MVC contraction.

Some studies evaluated the difference between holding time between subjects with pain and healthy subjects. Harris et al.,[33] found that healthy subjects had an average holding time of 38.95 seconds (SD=26.4) and subjects with neck pain had a holding time of 24.1 seconds (SD=12.8) (an average of 14.85 seconds lower holding time for subjects with pain). Kumbhare et al.,[57] also found WAD grade II subjects had a reduced holding time when compared to healthy subjects (subjects with WAD=11.2 seconds and healthy subjects=118.9 seconds). Ljunquist et al.,[53] Dumas et al., [58] Watson[59], and Watson and Trott [60] had similar results. The results of the present study partially agree with the results of these previous studies in the fact that there was a difference in holding time between subjects with mixed TMD pain compared to healthy subjects (at 25% MVC). However, the holding time differences between healthy subjects and those with pain found by previous studies were more marked than in the present study.

Most of the analyzed studies [33, 53, 58-60] did not report the level of dysfunction of their sample. Only Kumbhare et al., [57] reported the level of neck disability of their sample. Their subjects with severe neck disability (mean NDI = 25.6) presented with a significantly reduced holding time in comparison to healthy subjects. The level of disability of the subjects presented in the present study was only mild (mean NDI = 12.38) which could explain in part the difference with Kumbhare et al.'s,[57] results. In addition, no direct comparisons could be made since none of the other studies investigated the holding time at different percentages of MVC as did the present study. This factor could also explain the differences found between the present study and previous studies. Furthermore, the level of neck disability in our TMD sample was lower than what was reported in one of the previous studies investigating endurance.[57] This could partially explain why the differences in holding time with healthy subjects were not so evident.

Some studies [57, 64] have pointed out that the evaluation of endurance is limited by the presence of pain and sometimes is difficult to differentiate if a test is measuring "muscle endurance" or "pain tolerance". In our study, only 2 subjects could not perform the test because of presence of unacceptable pain during the preparatory phase. The remaining subjects completed the test. Subjects were told to stop the test if they felt that the pain was unacceptable. However, no subject other than the two mentioned stopped. Subjects were not asked the level of pain nor the level of exertion during the test which could be considered limitations of this study. Future research could add these measurements during the procedure to determine whether these factors could contribute to the final outcome.

Subjects with mixed TMD had statistically significantly lower holding times at 25% MVC than healthy subjects and subjects with myogenous TMD. The fact that subjects with pain had reduced endurance times at lower levels of contraction (25%MVC) has been also reported in other studies investigating endurance in subjects with neck pain using more sophisticated instrumentation [65, 66]. According to Moseley and Hodges [67], pain is essentially motoric (related to movement) and it is not surprising that people with pain usually develop abnormal movement patterns. It has been reported that experimental muscle pain decreased the firing rates of active motor units during isometric contractions, [68] and caused associated changes to motor output such as increased activity or delayed onset in related synergists and antagonists, modifying the muscular synergies in a given task.[69, 70] Thus, it is thought that the presence of pain could trigger these motor strategies. In the present study, since subjects with mixed TMD had a more severe disability in the jaw, neck and also presented with longer time of symptoms and more intensity of pain than subjects with myogenous TMD, they could present with greater motor alterations.

In addition, a reduced endurance in patients with mixed TMD at lower loads could be explained by altered coordination of cervical flexor muscles at lower levels of contraction or one could speculate that a greater role or percentage of the type II muscle fibers in cervical flexor muscles as well as fiber transformation of the cervical muscles as reported by Uhliget al., and Weber et al., [71, 72] could exist. These authors found a transformation of slow-twitch oxidative type I fibres to fast-twitch glycolitic type IIB fibres in the majority of the SCM, omhyoid, and longus colli specimens within the first 2 years after the onset of the cervical symptoms independently of the patient's age and sex and was the same for different etiologies. However, the severity of pain and degree of disability was not investigated in these studies, and thus it could be speculated that subjects with more severe or greater disability presented with more motor alterations than those with less severe pain. Furthermore, since the cervical muscles have a dual function- stabilizers and mobilizers of the cervical spine and they commonly act under low load levels, [73-76] it is more likely that impairments could be seen at this level of loading and not with greater levels of load that are more substantial in magnitude, but are shorter in duration.

The results of all studies dealing with holding time demonstrate a great variability among samples. This variability also has been seen in other physical performance tests such as maximal strength, [77] endurance test for cervical extensor muscles, [78] and maximum endurance time of other muscular groups such as the upper limbs and back/hip muscles,[64, 79] This variability can be attributed to different protocols used, sample tested, and also possibly to some anthropomorphic characteristics of the subjects such as age, muscle length and mass, and weight of the limb (head).[57] Thus, with this variability in mind, it is difficult to determine cut offs for normal values. It would also be desirable to have normative values of endurance holding times at different levels of MVC in a representative sample of healthy subjects. However, holding time values could be used in a better way to set clinical goals during treatment of subjects with painful conditions given the high intra- and inter-reliability reported by these tests under different conditions.[80] Endurance evaluation is considered clinically relevant since training for endurance has been associated with a reduction in symptoms in patients with pain and thus could be use as determinant of improvement.[34, 35]

According to the results of this present study, no significant associations between neck disability, jaw disability, and clinical variables were associated with the neck flexor endurance test. Therefore, these results do not support the 3rd, 4th, and 5th hypotheses of the present study. These findings are not in agreement with the findings of Kumbhare et al. [57] who compared the association between neck disability and neck flexion endurance test in a group of healthy subjects and subjects with whiplash disorders (WAD). They found that the neck flexion endurance test was significantly associated with the neck disability measured with the Neck Disability Index. They found that for each second of increase in the neck flexor endurance test, a decrease of 0.0872 points in the NDI occurred. Although this association was statistically significant, we question the clinical significance of the results since the value of the association coefficient is small. Furthermore, disability is complex construct and many factors such as stress, [81] a person’s coping status, self-efficacy,[82] patient’s beliefs, lifestyle, and environmental factors [83] could determine disability. Thus, endurance evaluation could just be a part of the physical aspect of disability but cannot be considered as a direct measure of disability.

The test evaluated in this study resembles the test used in clinical settings and appears to have face and content validity. However, higher levels of validity such as construct validity using electromyography are needed. Future research using electromyography in this population should be conducted to determine if reduced endurance is present in specific muscles with a more objective tool.

7.8 CONCLUSION

Based on the results of this study, there was a significant difference in holding time at 25% MVC between subjects with mixed TMD when compared with subjects with myogenous TMD and healthy subjects. This implies that subjects with mixed TMD probably had less endurance capacity at lower level of contraction (25% MVC) than healthy subjects and subjects with myogenous TMD. These results can help guide clinicians in the assessment and prescribing more effective interventions addressing this impairment for individuals with TMD. No significant associations between neck disability, jaw disability, and clinical variables with neck flexor endurance test were found. Future research using electromyography to evaluate fatigue in this population should be conducted to determine if reduced endurance is present in specific cervical muscles with a more objective tool.

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8 CHAPTER 8

ELECTROMYOGRAPHY BASIC CONCEPTS

8.1 INTRODUCTION

Electromyography (EMG) is the study of muscle function through the analysis of the electrical signals emanating during muscular contractions [1, 2]. Electromyography has been used for many years to study muscle behavior and has been recognized as a valid tool to monitor the muscle activity under different conditions and to evaluate muscle fatigue.[2-11]

Electromyography may be used to measure muscle activity noninvasively, using surface electrodes placed on the skin overlying the muscle, or invasively through wire or needle electrodes.[1, 12-14] The use of EMG is based on the electromechanical coupling in muscle. The functional unit of a muscle contraction is a motor unit that is comprised of a single alpha motor neuron and all the muscle fibers that it innervates. The muscular fibers contract when the action potential of the motor nerve reaches its threshold. The resulting depolarization generates an electromagnetic field and the potential is measured as a voltage.[1, 3, 6] In others words, the EMG recording is the summation of the motor unit potentials within the pickup area of the electrode. Since the muscle is not compartmentalized or isolated, the electrical signals generated from one motor unit can reach another and sum up their potentials, which is captured by the electrode and expressed as an EMG signal.[1] A visual record of these signals is called an electromyogram.[12] There are 2 main types of EMG: clinical (diagnostic) and kinesiological (used in movement studies). Every technique has its own objectives. Diagnostic EMG typically is performed by physicians, such as neurologists and physiatrists, who want to evaluate the characteristics of the motor unit action potentials for duration and amplitude to diagnose neuromuscular diseases and injuries. Kinesiological EMG is more commonly used in kinesiology to determine the behavior of the muscles when analyzing movements. This type of EMG is used by kinesiologists, physical therapists and ergonomists. In this case, the objective of the EMG is to determine the timing of the muscle contraction, analyze the function of the body movement and the muscular actions, and to investigate the process of muscular fatigue.[1, 3, 6, 8, 15] Depending of the objective of the EMG, the electrodes may be needle, wire or surface electrodes. Surfaces electrodes are more commonly used in analysis of the movement, kinesiology, and physical therapy. The electrical signals generated in the muscles are captured by the electrodes on the surface.[1, 3, 6, 8, 15] Wire and needle electrodes are more commonly used in medicine for diagnosis of neuromuscular diseases. [1, 3, 6, 8, 15]

Electromyography is a technique that depends on many factors to provide information about the muscle and its nerve supply, and of course, has limitations in the interpretation of the end results. The information must be interpreted very carefully and responsibly according to the limitations of this technique. [1, 3, 6, 8, 15] Technical considerations such as the electrodes placement, preparation of the skin, amplifier location, and use of filters are very important when using EMG.

Meticulous care is required in skin preparation. Skin cleansing, hair shaving, or skin abrasion are required in some cases to ensure good signals. The electrode's placement has to be precise, following careful landmarking, in order to properly capture individual muscle activity. The interelectrode distance, size, shape, and material of the electrodes must be considered to standardize the EMG protocol and obtain a signal of good quality.[16, 17] Analysis of the results has to be clear and well defined in order to precisely determine the behavior of the muscles in the time or frequency domains. The type of information provided in an EMG analysis will depend on the researcher's objectives. The most commonly used ways to process EMG signal are : Half –wave rectification (deletion of all negative aspects of the signal), full-wave rectification (absolute value of the entire signal), linear envelope (low pass filtering of the full –wave rectified signal), root mean square (RMS) (basically squaring the signal, taking the mean of a timed determined window- about 100-200 ms, and then taking the square root of that signal), integrated EMG (i.e. area under the rectified curve can be determined for the entire activity or for pre set time or amplitude values) and finally the frequency analysis (typically determined via Fast Fourier Transformed-FFT-, from the power density spectrum.)[5, 12, 13, 15, 18-22]. When using non-stationary contractions wavelet analysis is more sensitive to detect changes in frequency than the FFT.[23-25] All processing methods have advantages and limitations (they will be described later), however, the most commonly used technique currently for analyzying the power of the signal is the root means square (RMS), since this gives the physical meaning of the signal, in other words , the real energy.[8]

Another element to consider when using EMG is the normalization procedure. For comparisons of EMG from task to task or person to person, data needs to be presented in a common format. Several procedures have been developed for both the time and amplitude domains. It is suggested that ideally the normalization procedure be done in the same position or with the same activity that the muscle is acting.[2, 8, 13, 15, 18, 26, 27] However, this is not always possible. Some authors have recommended the use of the maximal voluntary contraction (MVC) as a parameter of normalization. [27] Others suggest the use of submaximal contractions of the muscles evaluated [28], and keeping the same conditions of velocity and position of the testing procedure.[11] There is no standard process of normalization today; however, the most important fact is that the EMG must be normalized, since the activity without normalization is useless if the objective of the EMG is to quantify the signal and compared among subjects. [2, 8, 13, 15, 18, 26, 27, 29, 30]

Another factor, which makes the interpretation of the EMG signal difficult, is cross- talk. Cross talk is the interference of the EMG signals from adjacent muscles or deeper muscles that are within the pickup area of the electrodes. Although there are no fixed solutions for this problem, the size of the electrode (small), location of the electrode, and whether the electrode configuration is differential or not, contribute to decreasing the noise caused by additional muscles or the environment.[4, 8, 15, 20, 31-33]

EMG with its considerations and limitations and with responsible use can be very helpful to understand muscle behavior. For example, EMG can help to determine when the muscle is contracting or active, determining activation times for different muscles. In addition, EMG can help determining abnormal patterns of activity and also can help establishing a fatigue index for the muscles. All of these uses are meaningful for kinesiologists, physical therapists, physicians and people who work in movement analysis as they answer some of the questions related to the behavior of the muscular system. However, as De Luca said,[8] EMG is a technique that is commonly abused, and many people do not take into account the limitations of this technique, not only the technical limitations (e.g. type of amplifier used, electrodes, preparation of the skin, noise), but also physiological limitations (such as number of motor unit action potentials (MUAPs) firing, type of muscle being tested, or nature of the EMG signal). As well, additional knowledge is required in order to understand these limitations. Thus, when using EMG, many considerations must be taken into account when interpreting and analyzing the data in order to provide real and accurate information.[4, 6, 8, 15, 20, 31-33] Therefore, the basic considerations about surface EMG will be described in the next section.

8.2 UNDERSTANDING EMG: ORIGIN OF THE SIGNAL

Muscles work through a basic unit called a motor unit. A motor unit is comprised of one motoneuron and the muscular fibers that it innervates. When there is an action potential in this motor unit, all of the fibers of this motoneuron activate. When the postsynaptic membrane of a muscle fiber is depolarized, the depolarization propagates in both directions along the fiber. The membrane depolarization is accompanied by movement of ions, which leads to the development of an electromagnetic field in the vicinity of the muscular fibers. An electrode will detect this magnetic field as voltage relative to the ground electrode.[4, 6-8, 34] In human muscle, the amplitude of the action potential depends on the diameter of the muscle fiber, the distance between the active muscle fiber and the detection site, and the filtering properties of the electrode. The amplitude increases as the radius of the muscle increases, and decreases proportionally as the distance between the active fiber and the detection site increases.[4, 6-8, 34]

The duration of the action potentials will be inversely related to the conduction velocity of the muscle fiber, which ranges from 3 to 6 m/s. The relative time of initiation of each action potential is proportional to the length of each nerve branch, and the time that is taken for the depolarization to reach the pickup area. This relative time of initiation is inversely proportional to the conduction velocities of the nerve branches and the muscle fiber as well.[6, 34]

The waveform and the frequency spectrum of the action potentials are affected by the tissues that are between the muscle fiber and the detection site. The tissue acts as a low pass filter. This means that, as the signal passes through body tissue, high frequencies of the waveform will be attenuated (decreased). Therefore, low frequency components pass through tissues with less attenuation than occurs with the high frequencies. This effect is minimized for indwelling electrodes because they are closer to the active muscle fiber.[22, 35]

Muscle fiber action potentials are registered as a signal, which is the result of spatial-temporal superposition of the individual action potentials or motor unit action potentials (MUAPs). If some muscle fibers, belonging to other motor units, are closer to the pickup area, their MUAPs will also be detected. However, the shape and amplitude of these muscle fibers MUAPs could be different. Therefore, it is not surprising that under one electrode, different shapes and amplitudes from different MUAPs are registered. [4, 6, 8, 13, 34]

It must be emphasized that the amplitude and shape of observed MUAPs are a function of the geometrical properties of the motor unit (active fibers related to the electrode), muscle tissue, detection electrode properties, amplifiers properties, and filtering properties of the electrode that will be discussed below. [4, 13]

8.3 CHARACTERISTICS OF THE SIGNAL

The EMG signal is the electrical manifestation of the neuromuscular activation associated with a contracting muscle.[4] The amplitude of the EMG is random in nature and can be represented as a Gausian curve (normal distribution).[7] The amplitude of the signal can range from 0-10 mV (peak to peak) or 0- 1.5 mV (root mean square-RMS)[7]. The usable energy of the signal is limited to the 0-500 Hz frequency above the electrical noise level. [29] There are 3 primary types of EMG visual displays: raw signal, spectral analysis, and processed signal.[15]

8.3.1 RAW SIGNAL

Raw signal is the original and most known representation of the EMG signal. It represents the unprocessed signal, peak to peak, without any intervention or analysis. It is the representation of the action potentials, summated, that reached the electrode. These action potentials are amplified and their sinusoidal nature is presented on the screen, as positive and negatives extremes.[15] (Figure 8-1).

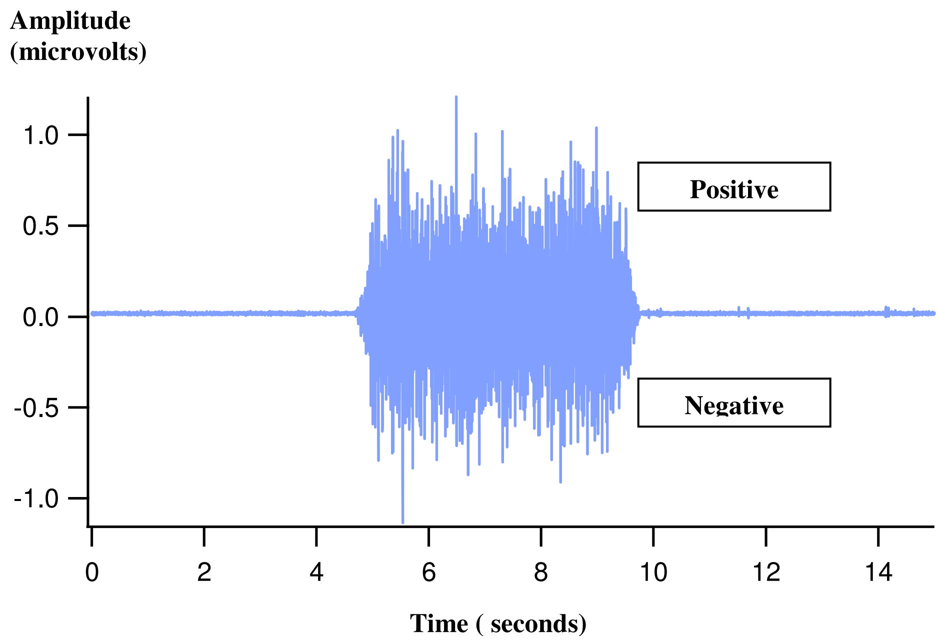

Figure 8-1: The raw signal of an Electromyographic recording that oscillates in both directions, positive and negative. The vertical line expresses the amplitude of the signal and the horizontal line of the graph expresses the time. The unit of measurement of raw tracing is microvolts (peak to peak). Analog signal taken from the sternocleidomastoid muscle (time/amplitude graph). Sport Therapy Laboratory, Faculty of Rehabilitation Medicine -University of Alberta, Canada.

8.3.2 SPECTRAL VIEW

The energy from muscles has a frequency spectrum and thus, the EMG signal can be displayed in order to see its range of frequencies. This is called "Power spectral density" or also called "frequency spectrum of the EMG signal", which shows the frequency components of the EMG signal as a function of their occurrence. This procedure is obtained through a mathematical procedure called Fast Fourier Transformations (FFT) that decompose the signal into its frequency components.[15]

Figure 8-2 illustrates the power spectral density of the EMG for a muscle. The height of the curve at any given frequency indicates how prevalent the muscle energy is at that frequency. In this case, the prevalent frequency is concentrated between 20-150 hz approximately (Figure 8-2).

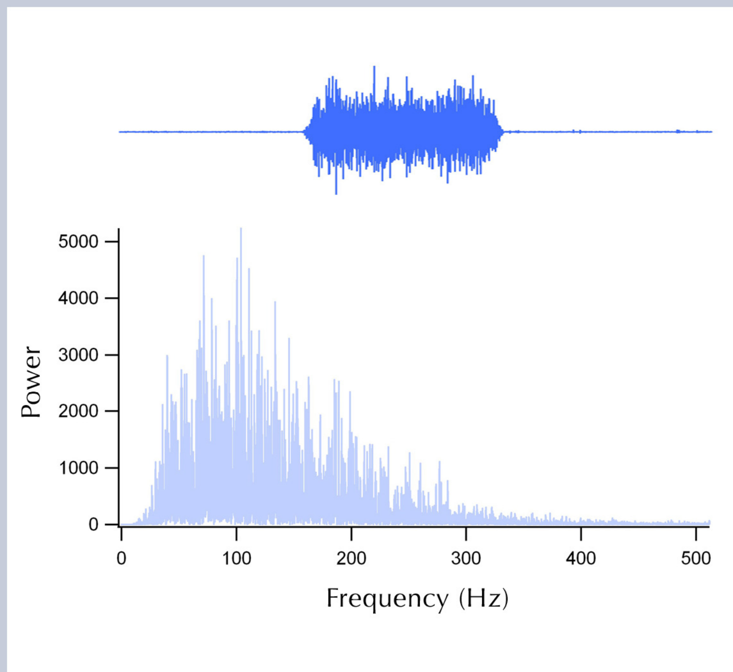

Figure 8-2. Frequency Spectrum of the EMG Signal from the Sternocleidomastoid Muscle. Sport Therapy Laboratory, Faculty of Rehabilitation Medicine, University of Alberta, Canada.

Processed signal will be discussed later on in this chapter.

8.4 FUNDAMENTAL CONCEPTS IN EMG SIGNAL ACQUISITION

Contemporary analysis of EMG is provided by computers. However, this requires that the signal be expressed as numerical sequences. This process, which involves detected signals being converted into numerical sequences, is called "analog-to-digital conversion". Analog signals are voltage signals and the amplitude of these signals varies continuously throughout their range. The process of conversion of the signal from analog to digital generates a sequence of numbers that represent the amplitude of the analog signal at a specific point in time. The resulting signal is called "digital signal". In this case, to convert the analog to digital signal, the analog signal has to be sampled. [36]

8.4.1 WAVEFORM SAMPLING: THE SAMPLING FREQUENCY

The process of digitization is defined by the concept of the sampling frequency. This sampling frequency is a critical value in establishing the accuracy and the reproducibility of the sample signal. Therefore, the minimum acceptable sampling frequency of a signal is a critical issue, if one wishes to correctly reproduce the original analog information. Based on the Nyquist frequency theorem, it is said that to correctly recreate a sinusoid wave, it must be sampled at no less than twice its frequency. Violating this principle leads to an incorrect reproducibility of the signal, which is typically referred as "aliasing".[36]

This phenomenon of undersampling results in aliasing. It is strongly recommended that sampling of the EMG signal is performed at least at 1000 Hz, as stated by the Nyquist theorem. Sampling of the EMG signal at less than 1000 Hz (samples / second) may distort the signal due to aliasing.[36]

8.4.2 MAXIMIZING THE FIDELITY OF THE EMG SIGNAL: HOW TO MAKE THE SIGNAL LESS CONTAMINATED (MINIMIZING THE SOURCE OF NOISE)

In order to obtain a signal of good quality, it is desirable to get an EMG signal that contains the maximum amount of information and the minimum amount of contamination from electrical noise.[7, 8, 13-15, 17, 21, 33] Noise from the detection and recording equipment cannot be eliminated, but it can be reduced using high quality and good component design involved in the data acquisition. The ambient noise originating from electromagnetic radiation caused by things such as radio, television, electrical power wires, light bulbs, and fluorescent lamps also distorts the signal. Ambient noise ranged from 50 or 60 Hz radiation from these power sources. The noise from motion artifacts (from the interface between electrode and skin, and from movement of the cable connecting the electrode to the amplifier) has most of its energy in the frequency range of 0-20 Hz, and can be reduced by proper design of the electrical circuit.[4, 17] Another source of noise depends on the characteristic of the EMG signal. This is random in nature, which means that frequencies lower than 20 Hz are unstable,[8, 17] since the firing rate of the motoneurons is quasi random in nature (i.e. not all fire at the same time). Therefore, this phenomenon is considered as a noise or unwanted signal, which has to be removed from the wanted signal through the filtering.[8, 13-15, 21, 33, 36]

Evaluation of the raw signal is essential to guarantee that there is no artifact interference. The signal can be monitored on an oscilloscope with a determined gain or be evaluated by the frequency spectrum analysis to verify the domain frequency of the recorded signal.[33]

8.4.3 ELECTRODES

One of the most important aspects of the EMG is to have equipment designed with the highest quality to ensure a good signal. The electrode construction is one the most critical aspects of the electronic apparatus which is used to obtain the signal.[8, 17] Electrodes have to be harmless and must be close enough to the muscle under study to pick up the current generated when the muscle contracts. The segment of the electrode which makes direct electrical contact with the tissue is referred to as the detection surface. In EMG, they are used singly or in pairs (i.e. monopolar and bipolar configurations respectively).

8.4.3.1 Electrode Geometry

When EMG use began, researchers gave little attention to the configuration of the electrodes, but were interested in the quality of the EMG signal itself. [8] Today, it has been realized that the design of the electrode is one of the important elements in the capture of a good signal. [17]

The major points to consider are:[8]

8.4.3.1.1 The signal to noise ratio of the detected signal:

The amplitude of the signal is directly proportional to the distance between the detection surfaces. According to De Luca, [8] a distance of 1 cm between electrodes is sufficient to obtain a good signal. The distance between electrodes needs not to be too far apart to detect a signal that is representative of the whole surface of the muscle since motor units are randomly scattered throughout the cross sectional area of the muscle. Thus, any location on the muscle contains motor units representative of that muscle. The distribution of the frequencies in the spectrum as well as the bandwidth is affected by the distance between the detection surfaces. The greater the number of fibers covered by the electrodes, the greater the amplitude of the EMG signal.

8.4.3.1.2 Bandwidth:

The single differential electrodes have a spatial filtering, provided by the electrode configuration. This filter can be expressed as a bandpass filter in the frequency domain of the EMG (i.e. the filter filters a specific frequency of the signal). The objective of this bandpass is to capture the full frequency spectrum of the EMG signal and eliminate the noise at higher frequencies.[8, 17]

8.4.3.1.3 Muscle sample size:

The muscle fibers of motor units are distributed throughout most of the muscle cross section. Therefore, the size of the muscular sample does not have to be very large to be representative of the specific motor unit activity.[8]

8.4.3.1.4 Cross talk susceptibility:

The greater the width and length of the detection surfaces and the greater the inter-electrode distance, the greater the probability of catching information from adjacent muscles. Therefore, if this phenomenon is a concern, it is necessary to reduce the electrodes size. [8]

8.4.3.2 Electrode as a Transducer:

An electrode is made of metal, and the electrolyte (contact medium) may be an electrolytic solution or paste. The electrode-electrolyte interface is the site where the electrical signal exchange occurs between the ionic current of the tissue and the electron current flow of the recording instrument. The quality of the signal depends on the ability of the interface to exchange ions for electrons and vice versa. The electrode has to provide minimal distortion and the highest signal to noise ratio. In order to reach these objectives, some specific requirements have to be considered:[8, 17]

8.4.3.2.1 Electrode Configuration

8.4.3.2.1.1 Monopolar configuration

Monopolar configuration is the easiest setup for detecting electrical activity. This configuration involves placing an electrode with one detection surface in or on the muscle. The electrical potential at that point is then detected with respect to a reference electrode located within an electrically unrelated area (e.g. sternum, olecranon, acromion, or any bone prominence). This configuration detects all the signals (wanted or unwanted) within the pick up region.[8, 13, 20, 22, 29] The advantage of this method is its simplicity, while the main disadvantage is the signal contaminated by noise, which cannot be eliminated.

8.4.3.2.1.2 Bipolar Configuration (also Called Single Differential Configuration)

The bipolar configuration uses two detection surfaces to detect two potentials within the muscle of interest relative to the reference electrode. The signals are fed into a differential amplifier and then the difference between the two signals is amplified. Therefore, any common signal is removed and any different signal from both detection sites is amplified. The accuracy with which the differential amplifier can subtract the signals is measured by the common mode rejection ratio (CMMR). A CMMR of 90 dB is generally sufficient to eliminate extraneous electrical noises. The bipolar configuration is a common method of configuration in EMG. The bipolar configuration serves as a bandpass filter whose bandwidth is a function of the spacing between the detection surfaces.[8, 13, 15, 17, 33] This method of configuration is more appropriate than monopolar configuration since it eliminates the unwanted signal and as a result, the quality of the signal is less contaminated with noise (Figure 8-3).

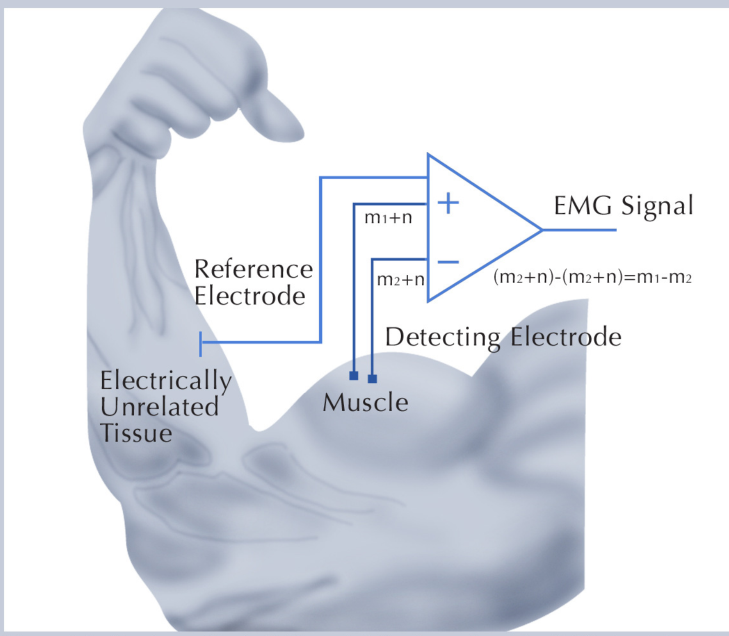

Figure 8-3. Bipolar or Single Differential Configuration. The EMG signal from the selected muscle is represented by ´m´ and the noise from other regions by ´n´. The single differential amplifier amplifies the signal which comes from the muscle of interest (different signal) and rejects or eliminates the common signal (noise). *(Adapted from De Luca, Surface Electromyography: Detection and recording , p. 8,1997)*

8.4.3.2.1.3 Double Differential Configuration

This technique consists of using a surface electrode which has three detection surfaces spaced equally apart. Two differential signals are obtained from detection surfaces 1 and 2, and detection surfaces 2 and 3.. In this case, the EMG signal has two levels of differentiation, diminishing the unwanted signal noise. Moreover, because of the electrode design, the pick up volume is reduced, filtering out the signals from further distances which correspond generally to signals from other muscles. [8] (Figure 8-4).

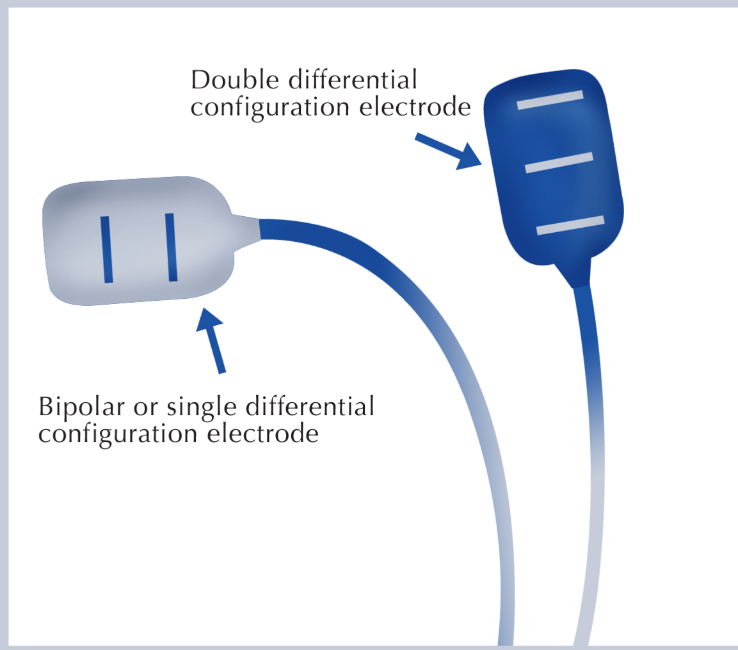

Figure 8-4. Electrodes with single and double differential configuration. Single differential configuration has only two sources of detection, and double differential configuration has three.

8.4.3.3 Non Invasive Electrodes: Surface Electrodes

These electrodes adhered to the skin and thus are not invasive. Generally, they are the same as those used for electroencephalography coupled with a saline gel or paste. These electrodes often use an Ag-AgCl electrolyte system.[8, 13, 15] The disc electrodes are very easily obtained and can be applied to the skin after very little training and with reasonable success, and they cause no discomfort to the subject. Electrical contact is improved by using a saline gel or paste. Dead skin has to be removed before the placement of the electrode in order to decrease the electrical impedance. Sometimes, some metals cause instability at the metal – electrolyte junction, setting up a polarization potential that may vary with temperature fluctuations, sweat accumulation, changes in electrolyte concentration of the paste or gel, relative movement of the metal and skin, and the amount of current flowing into the electrode. However, silver-silver electrodes are very popular in EMG due to their stability with respect to the above factors, they have light mass (250 mg), small size (11 mm diameter), and high reliability and durability.[8, 13, 15, 18, 20, 33]

An active electrode has been created to eliminate the skin preparation and conducting medium. These electrods are referred to as “dry electrodes” (Figure 8-4). Manufacturers have developed a small housing that places the preamplifier directly at the electrode site, therefore, the electrode plugs directly into the amplifier, eliminating the wire noise from the leads. The active electrodes are used more because they provide an EMG signal of greater fidelity and are very convenient to use. However, they have a fixed interelectrode distance, which cannot be changed thus they may not be suitable for all sizes of muscles. [20]

The disadvantages of the surface electrodes are that they can only be used to obtain signals from superficial muscles, and they are limited to bigger muscles.[13, 14, 20, 22, 33, 37] Pick up from small muscles generates cross-talk signals from adjacent muscles. By using manual resistive techniques to test isolated muscles, and observing the display of the EMG of the muscles, electromyographers can identify whether the electrical activity is being recorded from the muscle selected.[33] These electrodes are not selective to a specific area. Additionally, they require increasing the gain many fold to obtain a signal of good quality, which could magnify signals coming from another muscles as well. Nevertheless, they are convenient and comfortable for the patient. With the present technologies (e.g. active electrodes, single and double differential configurations), and depending on the electrode design, it is possible to decrease the limitations of the surface EMG.[7, 8]

8.5 FILTERING THE EMG SIGNAL

Once that EMG has been captured, it has to be processed in some way. The first level of processing is known as filtering**.** For a signal to be filtered, it is necessary to use a device (filter), designed to attenuate specific frequency ranges, while allowing others to pass, which circumscribes the frequency spectrum of the signal. The objective of signal filtering is to reduce the noise coming from different extraneous sources and to make the registered signal more pure containing the desired information. The frequency range which is attenuated is called the *stopband*, and the range which is transmitted is called the *passband*.

8.6 PROCESSED SIGNAL: ANALYSIS AND PROCESSING OF THE SIGNAL

8.6.1 QUANTIFICATION OF THE EMG SIGNAL: TIME DOMAIN ANALYSIS

The EMG signal has to be quantified in some way. This process involves a mathematical process, using numbers that describe the amount of muscular energy expended. The EMG signal has positive and negative values or voltages. It is not possible to simply sum up all of the voltages to determine the quantity of EMG activity of the analyzed muscle because all the negative and positive values can cancel out and the resulting sum would be zero. There are several ways to quantify the EMG signal:[15, 32] Peak to peak, integral averaging, and root mean square (RMS).

8.6.1.1 Peak to Peak

This method is the simplest method used for raw data recordings. It represents the amount of muscle energy measured from the top to bottom of the tracing. Generally, the peak-to peak measurement is summed and averaged over a period of time. Peak to peak normal values for a muscle in the resting position might range between 2 and 10 microvolts. However, it is important to understand that these values can vary depending on the interelectrode distance, amount of fat tissue below the sensors, type of muscle that is being monitored and the particular characteristics of the amplifier used.[15, 32] This method is used only to test the signal qualitatively and also to visually observe the muscular timing.

8.6.1.2 Rectification

This technique is most commonly used to simplify the raw data. Rectification is designed to translate the raw signal to a single polarity. This translation can be performed by eliminating one polarity (negative), which is called “half wave rectification”, or by inverting one polarity, known as “full-wave rectification. The latter is preferable because all the information about the signal is preserved.[13, 15, 32, 33] This method was used previously to integrate the signal, in order to be able to obtain quantitative analysis. However, it is only a mathematical procedure that does not provide a measurement of the energy of the signal (Figure 8-5).

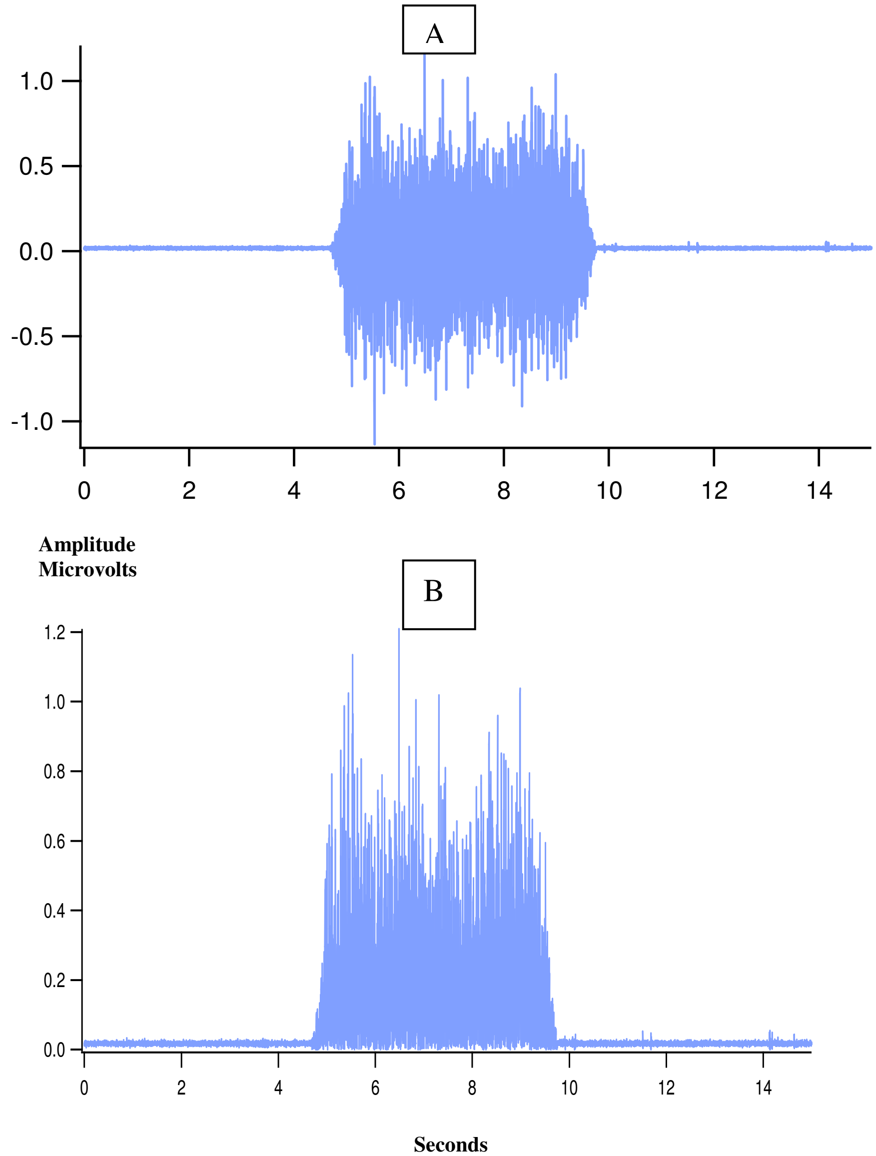

Figure 8-5: A raw signal (A) and the full wave rectified signal (B).

8.6.1.3 Integral Averaging (Also Called Integration)

Integration refers to the mathematical operation of computing the area under the curve of the signal. Because the integral of raw data is zero, it is necessary to full wave rectify the raw signal to obtain the absolute value. [32] The values obtained by this procedure are V/s or mV/ms. For several decades, it has been commonly accepted that the preferred manner of processing the EMG signal was to calculate the integrated rectified value. However, according to De Luca,[7] this method has no specific physical meaning. Thus, a new method called “root mean square” was created.

8.6.1.4 Root –Mean Square Processing

The root-mean square (RMS) is a fundamental measure of the magnitude of an EMG signal. This method is considered as a ”Gold Standard” by many.[7, 11, 16] The RMS process is a method that allows consistent, valid, and accurate measurements of noisy, nonperiodic, nonsinusoidal signals. RMS is not affected by the cancellation caused by the superposition of motor unit potentials that make the RMS procedure more useful than the other previously described. This method is the most commonly used at the present time because it provides less distortion, when converting an analog signal to a digital form (Figure 8-6).[2, 4, 8, 14, 15]

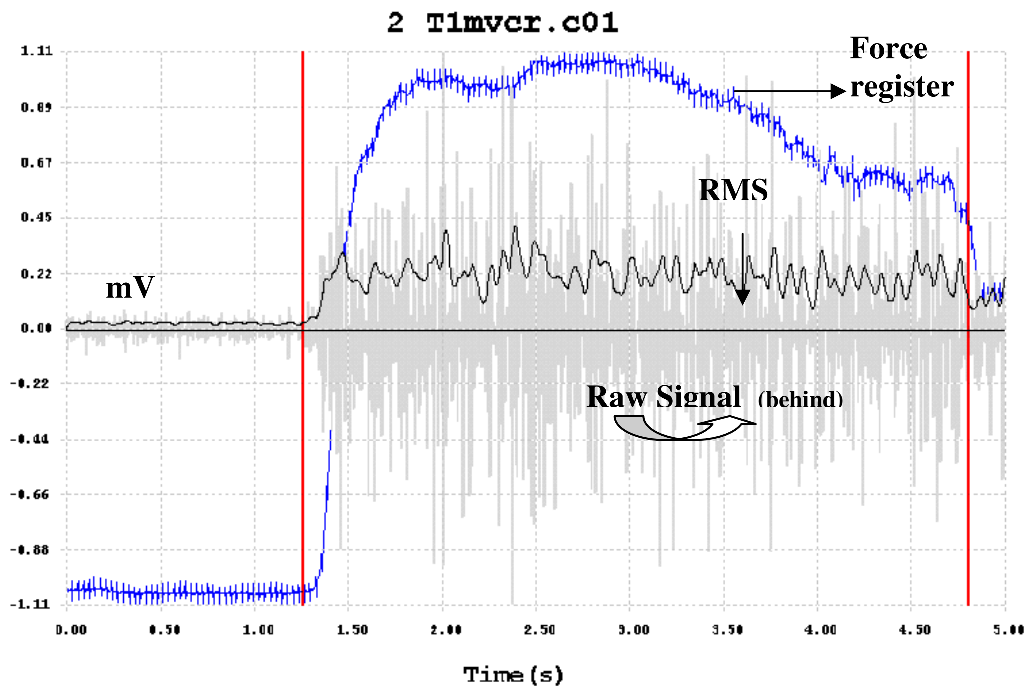

Figure 8-6: A Graph with the Raw Signal and the RMS Representation. Ergonomic Laboratory, Faculty of Rehabilitation Medicine, Department of Physical Therapy-University of Alberta, Canada.

8.6.2 QUANTIFICATION OF THE EMG SIGNAL: FREQUENCY DOMAIN ANALYSIS

The analysis of the EMG signal in the frequency domain involves measurements and parameters that describe the aspects of the frequency spectrum of the signal [5]. Spectral analysis can be understood as the decomposition of a signal into components of different frequency.[38] The most common analysis is the Fast Fourier Transform (FFT) which obtains the power density spectrum of the EMG signal when using static contractions (Figure 8-2). The FFT is a mathematical technique applied to the signal in which the time to frequency domain transformation is determined. When using non-stationary contractions, wavelet analysis is more sensitive for detecting changes in frequency than the FFT.[23-25] The power density spectrum of the EMG signal is affected by recruitment, firing rate, fatigue, and filtering, making the power spectral analysis very useful for determining the fatigue of the muscles and the behavior of the MUAPs while the muscle is contracting. [2, 4, 8, 14, 15]

There are three parameters obtained with FFT (Figure 8-7):

1. **The Median Frequency (MDF)**: the frequency that divides the power spectrum into two equal halves.[4, 8, 15]

2. **The Mean Frequency (MNF)**: the average frequency of the EMG spectrum.[4, 8, 15]

3. **Width of the Spectrum**: the range or width of the whole spectrum. In other words, it is the range of frequencies exhibiting power or activity. It is useful to know what the range of the dominant frequency is since it shows the range of all frequencies and also the observer can visually distinguish from the curve where the frequencies are concentrated.[4, 8, 14, 15, 18]

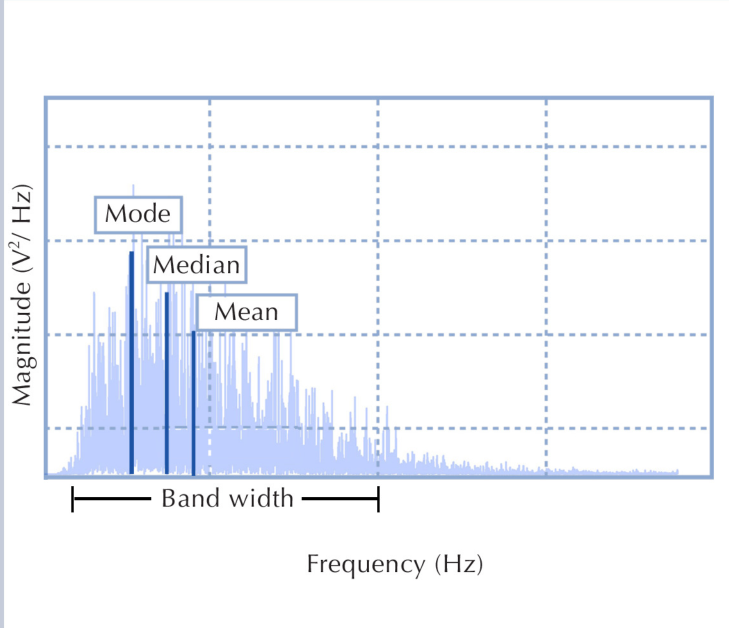

Figure 8-7. The spectrum of a signal after a Fast Fourier Transform (FFT) showing the mode, mean, median and the width of the EMG spectrum. *(Modified from Basmajian and De Luca, Muscle Alive, p.99, 1985)*

8.6.2.1 The EMG signal as a Fatigue Index

Fatigue has been an interesting topic not only for biomechanicians, but also for physiologists, engineers and physical scientists. Fatigue has been defined in different ways; nonetheless, the most accepted definition is "the point at which a contraction can no longer be maintained."[8] This definition, however, implies that fatigue occurs at a specific point in time, which provides some disadvantages as the fatigue would be detected only after fatigue has occurred. This definition is not suitable for practical applications in ergonomics since it is desirable to know the events that occur before or preceding the fatigue process in order to prevent or avoid its effects. An alternative method is provided by analyzing the power density spectrum of the EMG signal detected during a sustained contraction.[5, 8, 15, 18, 39, 40] The spectral modification of the signal is characterized by a compression accompanied by an alteration in the skewness of the shape of the spectrum of the EMG signal before the muscle becomes unable to sustain a determined force.[9, 40] The reasons accounting for the shift in the mean and median frequencies of the EMG spectrum remains a matter of debate.[41]

The analysis of the spectral domain of the EMG provides fatigue indices, which have a greater applicability for diagnosing and evaluating muscle fatigue. The fatigue index provided by the EMG analysis has increasingly been used to determine signs of fatigue because it has advantages over the previous mentioned approach.[8]

Contractile force from muscles can be obtained by monitoring the torque developed at a determined joint. However, this torque is not the expression of one isolated muscle, but the summation of the force of many muscles. Conversely, the EMG signal can be detected from individual muscles; so the spectral variable fatigue index can be used to describe the performance of one isolated muscle. The spectral analysis provides a continuous analysis of the muscle behavior showing the rate of the fatigue early in the contraction.

The spectral modification may be monitored and quantified by indicators of the frequency spectrum such as median, mean or mode frequency of the spectrum (defined previously) (Figure 8-7), or knowing the ratio of a low frequency to high-frequency bandwidths. The median frequency (MDF) has been commonly used as it is less sensitive to noise, signal aliasing (i.e. signal distortion), and is more sensitive to the fatigue process.[38] However, MNF also has been used and has demonstrated good reliability when analyzing fatigue.[42]

A fatigue analysis using EMG is based on the idea that during sustained contractions, the time duration of compound action potential of a muscle increases as the time of the contraction increases, which causes a compression of the EMG signal. This is shown by a shift of the median frequency to the left (Figure 8-8).[5, 8, 15, 43]

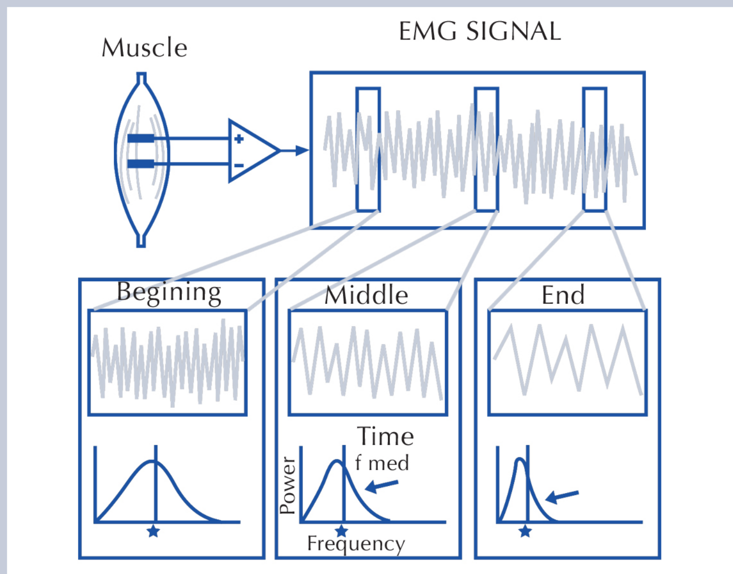

Figure 8-8. Spectral Modification of the EMG Signal during Sustained Contractions.The change in the median frequency along the EMG signal. At the end of the EMG signal the median frequency is displaced to the left side, where lower frequencies are. The muscle fatigue index is represented by the median frequency of the spectrum (*Adapted from De Luca .The use of Surface of Electromyography in Biomechanics p. 26, 1997)*

The factors that cause the frequency spectrum vary (because they alter the shape of the MUAP) include the electrode configuration, location and orientation of the electrodes, the architecture of the muscle and tissues, and physiological and biochemical events. If an anisometric (non-isometric) contraction is performed, all of these factors will influence the shape of MUAP, however, their causative influences are difficult to determine. Thus, it is recommended that the spectrum of the EMG signal detected during anisometric contractions be analyzed with more sensitive techniques such as wavelet analysis. On the other hand, for a constant force isometric contraction, the factors that affect the MUAP are conduction velocity and the depolarization zone of the muscle fibers.

8.7 Comparison of Quantified EMG Values across Muscles and Subjects: Normalization Procedure

EMG signals can change based on the recruitment and firing rate of motor units within the muscle. Generally, as more force is needed, more motor units are recruited. However, this phenomenon is not the same for every muscle. The myoelectric activity signal may change due to many factors. For example, change in the electrode location, change in tissue properties, or tissue temperature, [44] thickness of subcutaneous adipose tissue, muscle resting length, velocity of contraction, fiber type, age, sex, interelectrode distance, and impedance of the skin are just one of the factors that affect the EMG signal. Additionally, anthropomorphic differences between different recording sites and between individuals make the comparisons of the EMG signal difficult and comparisons must be made with caution.[15, 20] The absolute values of volts provide an inaccurate comparison of muscle function during different activities. For this reason, comparing the EMG activities between subjects and under different conditions requires a process known as "normalization".[8, 15, 22, 27]

There are many forms of normalization that use different values to normalize data. The most common use is to normalize the EMG data in the time domain (amplitude) as a percentage of the Maximal Voluntary Isometric Contraction (MVIC). When using EMG, it is necessary to normalize data by establishing the parameters of the EMG activity of the muscles and the force of the muscles measured in Newtons (Maximal Voluntary Referential Contraction-MVRC). This normalization must be performed before any and each testing, so that the data for each subject at different times can be compared.[8, 15, 22, 26, 27] Burden and Barlett [27] stated that this method should be used to normalize the amplitude of the EMG if the objectives are to compare data between subjects, muscles, tasks or to retain the natural variation between individuals.

If a study reports the results in microvolts without normalizing the data, comparison between subjects is impossible due to individual differences.[3, 8, 13, 18, 27, 32, 44]

Basically, the normalization procedure consists of registering the MVIC for every muscle being evaluated electromyographically and then when subsequent submaximal contractions of those muscles are performed, the EMG value will be expressed as a percentage of the MVIC. Caution should be taken when using MVIC since the EMG–force relationship is not linear over the entire force range and this relationship also varies among subjects and muscles.. Comparisons performed within subjects are more precise than comparisons across individuals.[44] In some circumstances, when MVIC cannot be performed by the subjects, a Known Referential Submaximal Contraction (KRSC) could be used for normalization. The KRSC is determined by the researcher and will depend on the aim of the study and the muscles used for the research.[45]

When dynamic activities are studied, the normalization procedure is more complex since the MVIC does not represent the activity performed by the analyzed muscles. This situation is due to the fact that now there are other factors such as the length-tension relationship, force-velocity relationship, and the location of the firing motor units relative to the surfaces electrodes that account for some of this information. In this case, another method, using the Submaximal Voluntary Contraction (SVC) could be performed. The signals are expressed as a percentage of this submaximal contraction. Additionally, to record contractions as a function of a dynamic movement, using the peak or mean values observed during the dynamic movement, could be a solution for dynamic movements.[2, 8, 27, 44]

It is not possible to select one normalization procedure for all occasions. The normalization procedure should be determined by the type of muscles, contraction used, type of movement, or tasks studied. In summary, the normalization procedure is necessary to compare trials, subjects and muscles. When the activity is isometric or the relationship is sufficiently linear between EMG and force, the MVIC should be used as a method of normalization. When the relationship is known to be non linear, submaximal contraction should be used as the method of normalization. If the studied movement is dynamic, the peak or mean of the EMG activity of that movement is used. It is important to notice that the reference contraction used should reflect the activity being studied. [2, 8, 27, 44]

According to Soderberg,[2] the MVIC should be used until the matter is further clarified in the literature. However, in order to have good results with this method, the subjects need to be trained, guaranteeing that the subjects exert the MVIC every time they are evaluated.

For the spectral analysis, the most common and recognized method of normalization is that in which the slope is normalized with respect to the initial value defined as the intercept of the regression curve or line with the y-axis (initial median frequency).[5, 8, 9, 46-48]

8.8 VALIDITY AND RELIABILITY OF THE EMG

Reliability is conceptualized or defined by Portney and Watkins[49] as reproducibility. It may also refer to the extent to which a test score is free from errors of measurement. According to these definitions, the reliability of the instruments and measurements that researchers use to evaluate different outcomes need to be reliable because without this reliability, one cannot be confident that good data has been collected, and therefore conclusions cannot be made.

Another prerequisite is the validity of the test or instrumentation used, which ensures that the test or the equipment is measuring what is intended to be measured[49]. Electromyography has been used for many years to study the muscle behavior and has been recognized as a valid tool for monitoring the muscle activity under different conditions and to evaluate the fatigue process.[2-11]

It is known that the measurements and instrumentation that one normally uses are not perfectly reliable and all humans respond with some inconsistency. As a result, EMG signals do not escape this fact and thus have to be analyzed in terms of their reliability. Reproducibility of EMG signals is important in longitudinal studies of muscle load as a risk factor for muscle pain or in evaluating some interventions in muscle behaviour.[50]

Some efforts have been made by authors in order to learn more about the reliability of the EMG signal with different procedures and different protocols. The reproducibility of the EMG depends on electrode placement, electrode contact area, source and amplifier input impedance, direction of movement of the extremity, type and velocity of muscle contraction, muscle length, tissue distance between electrode and muscle, and muscle temperature.[26] According to Sommerich et al.'s report,[50] few authors, who have studied cervical muscles, have reported reliability and repeatability issues related to EMG in their studies. However, reliability of EMG signals has been addressed under other conditions using different muscles. For instance, Bogey, Cerny and Mohamed[51] evaluated the reliability of wire and surface electrodes in gait analysis. They analyzed the variance ratio of the normalized values of the EMG in soleus muscle. Variance ratio, according to the authors, is a measure of repeatability of waveforms, with low values indicating high repeatability. This value is similar to the coefficient of variation used in other studies. The reliability of both electrodes (surface and wire) was found to be good and there was no statistical difference between them. Thus, the authors suggested that the use of normalized surface EMG or needle EMG in the evaluation of gait was reliable. Another study evaluated the short term, intermediate term, and long term reliability of the EMG signals of the knee muscles (i.e. rectus femoris, vastus medialis, and vastus lateralis). [52] These authors evaluated the RMS and the median frequency of these muscles in different conditions, test /retest intervals (within day repetition), and between day repetitions. The within day assessment consisted of evaluation of the EMG signal at 100% MVC (2 times) and then 2 times at 50% MVC , and finally, the EMG activity was measured at muscle fatigue. The results obtained by this study showed that the short term reliability of EMG was high, and long term EMG reliability was acceptable in both RMS and the median frequency. The EMG registered from rectus femoris was more reliable than that obtained from vastus lateralis or vastus medialis. The MDF (median frequency) intraclass correlation coefficient (ICC) for quadriceps within day evaluation was high (0.85-0.99), however, the ICC was only moderate between days (0.49-0.61). The root mean square's ICCs revealed by this study were good, however, only for rectus femoris. Also, RMS values when the muscle was fatigued were not reliable. The authors recommended that the following considerations be taken in account to obtain better reliability of the EMG signals in knee muscles: 1) use submaximal, and isometric contractions; 2) use reliable and stable positions of the limb and electrodes; 3) perform follow up as soon as possible; 4) obtain signals preferably from rectus femoris; 5) evaluate muscular fatigue through MDF shift.[52]

Additionally, Lehman,[53] investigating the EMG activity of erector spinae in quiet stance, obtained very good repeatability of the all EMG signals regardless of the normalization technique used for within subject evaluation (ICC> 0.75 for normalized and non-normalized signals). However, he found that the between-subject variability was high. Therefore, if the objective is to compare EMG between subjects, normalization of raw data is mandatory since the amplitude of the EMG raw data shows a large variability between subjects.

On the other hand, reliability, when testing abdominal muscles, was found to be site dependent. The transversus abdominus and internal oblique muscles obtained good reliability for all positions of the arm (shown by activation of the abdominal muscles prior rapid limb movement). However, the reliability of the external oblique was not good for any of the movement directions. Moreover, the rectus abdominus only obtained a good reliability when the arm was moved in flexion. These results indicate that the sites of the external oblique and rectus anterior muscles used for this study [54] were not good for obtaining good EMG reliability, and thus were not good for testing the neuromuscular response of these muscles to rapid limb movement. The anatomical complexity of the abdominal muscles is one of the main problems that affect the repeatability of EMG in the abdominal region, in addition with the large amount of adipose tissue that exists around the abdominal muscles.[54]

EMG reproducibility was excellent when analyzed by the coefficient of repeatability described by Bland and Altman in a study of the trapezius EMG activity in a group of workers. As well, there were no statistical differences in the parameters used in different evaluations (i.e. static, median and peak EMG amplitude), supporting a good reliability of the EMG measurements. The stability of the EMG normalization was improved by using biofeedback when the subjects exerted MVC. The authors concluded that biofeedback was useful for controlling the maximal level of muscular activity of trapezius and for decreasing the variability of the EMG values over time.[26]

Yang and Winter [28] showed EMG reliability to be higher for submaximal voluntary isometric contractions than for MVC. On the other hand, Ebenbichler et al.[55] showed high ICCs during repetitive lifting at 14 muscle sites (L5, L2, T10, upper trapezius, gluteus maximum, vastus lateralis, biceps femoris bilaterally) reflecting the reproducibility of values between sessions, that ranged between 0.89 and 0.99 for short term (2 hours) and long term (2 weeks) respectively. Koumantakis et al.,[56] also concluded that the EMG measures derived from time-frequency analysis procedures were reliable and supported the use of this technique in monitoring muscle fatigue during dynamic real world tasks. Nevertheless, RMS values did not obtain a good repeatability, shown by large standard errors of the measurement, demonstrating that RMS is not a reliable parameter to be used in fatiguing contractions for back muscles (doing the Boering –Sorensen test and 60% MVC from the upright position). Moreover, Lehman[53] stated that intraclass correlation of the EMG signals of the paraspinal musculature on 3 separate days during quiet stance with 3 different normalization techniques—percent maximum voluntary contraction, percent submaximal contraction, and percent averaged submaximal contractions were repeatable with an ICC> 0.75. These data, related to degree of repeatability and intraclass correlation coefficient (ICC) are in agreement with those of other studies performed by Lariviere et al.[57] who found that a specific EMG parameter called "neuromuscular efficiency" (NME), which suggested that a weak subject activates more motor units to exert a given absolute force than a stronger subject, showed an acceptable reliability with an ICC>0.65, and with a standard error of measurement < 25%).

Thuresson et al.,[48] analyzed the intrarater reliability of the frequency analysis in cervical muscles on the same day and between days. They found that median frequency slope showed generally better reliability parameters the longer the contractions lasted. They obtained an excellent ICC (0.83) for the upper neck, intra-day, using 45 second contraction. For the lower neck, they also obtained good repeatability (ICC=0.66). In addition, data from SCM on all occasions showed good to excellent repeatability, however with a higher variance between subjects than the extensor cervical muscles. The reliability obtained from the normalized slope for SCM muscle was between good and excellent with ICC values ranged from 0.69-0.82. For the upper neck (electrode position) and lower neck, the ICC values were lower than for SCM. However, ICCs were considered good (ICC: 0.57-0.89). In addition, they obtained good to excellent ICCs for the initial median frequency and low coefficient of variation for the intra-day analysis for all muscles. However, inter-day reliability for the initial median frequency was lower for SCM and the upper neck. Gogia and Sabbahi,[58] reported similar results for the initial median frequency as Thuresson et al.,[48] confirming the high reliability of this parameter when analyzing fatigue in muscles during short isometric contractions.

A recent report [42] about the reliability of the EMG when applied to SCM and scalene muscles found that good levels of repeatability were identified for the initial value of the MNF for scalene muscles and SCM muscles (normalized standard error of the mean (nSEM) = 3.5% and 7.5 % respectively). Excellent values of (nSEM) (from 2.6 to 7.2%) were found for initial values of MNF for SCM and scalene muscles. Moreover, the slopes for MNF demonstrated an acceptable reliability (standard error of the mean<15%) for these muscles. These results allow such parameters to be used in the manifestations of localized muscular fatigue.[42]

In summary, reliability of the EMG has shown to be good based on the majority of the studies analyzed. However, it is important to note that in order to have good EMG signal reliability; the protocol used in each situation has to be very strict and the same for all subjects on different occasions. From the procedure of cleaning the skin to the moment of analyzing the signal, every step has to be repeated in the same order, and in a same rigorous way to keep the data as stable as possible. The normalized signal has been recognized as a good procedure to perform when the objective is to compare the EMG signals in different subjects under different conditions (see section of normalization). According to Sommerich et al.,[50] normalization has demonstrated to increase the reliability of the EMG endpoints and is recommended by experts when using EMG.

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9 CHAPTER 9

ELECTROMYOGRAPHIC EVALUATION OF THE CERVICAL FLEXOR MUSCLES IN PATIENTS WITH TEMPOROMANDIBULAR DISORDERS WHILE EXECUTING THE CRANIOCERVICAL FLEXION TEST (CCFT)

9.1 INTRODUCTION

Temporomandibular disorders (TMD) has commonly been associated with symptoms affecting the head and neck region such as headache, ear related symptoms, cervical spine dysfunction, [1, 2] and altered head and cervical posture.[3-13] It has been reported that pain in the cervical musculoskeletal tissues may be referred to cranial structures including the jaw muscles,[14, 15] and thus, a connection between cervical muscle dysfunction and jaw symptoms could exist.[16-19] Additionally, experimental animal studies have revealed considerable convergence of craniofacial and cervical afferents in the trigeminocervical nucleus and upper cervical nociceptive neurons.[20-25] All of this evidence has been implicated as the basis of pain localization and referral, and neuromuscular adaptations in the cervical and orofacial regions.[26-29]

Musculoskeletal disorders associated with the cervical region such as neck pain, cervicogenic headache (CEH), and whiplash associated disorders (WAD) present with abnormal muscle function of the cervical muscles.[30-32] Primarily, gross changes in strength and endurance have been observed. However, according to Jull et al.,[31] and Falla and Farina,[33] there are also more fine changes in motor activity such as changes in motor control. Reduced activation of deep cervical muscles, augmented superficial activity of sternocleidomastoid (SCMs) and anterior scalenes (ASs) muscles, and changes in feedforward activation, reduced capacity to relax the cervical muscles, and prolonged muscle activity following voluntary contraction could lead to a compromise in the control of the cervical spine and consequently lead to pain and dysfunction. Study of these muscular alterations has gained attention in the last few years since exercises addressing these motor control alterations have had good results in patients with cervical involvement.[34-36] Therefore, the assessment and treatment of the muscular impairments is considered to be a key element in the management of cervical disorders.

One of the most common methods to evaluate the performance of the craniocervical flexors muscles is the use of the craniocervical test (CCFT). The CCFT is a low-load test used to evaluate the performance of the deep cervical muscles (i.e. longus colli, and rectus capitis). The CCFT consists of the subject performing a craniocervical flexion (nodding) movement, which is performed by the deep cervical muscles. Superficial muscles such as SCM and the scalenes normally do not participate in this movement. The CCFT combines the action of flexion at the craniocervical junction, performed by the longus capitis, along with the flattening of the cervical lordosis, an action of the longus colli muscles. The pressure sensor detects this flattening of the cervical lordosis. Electromyographic activity of the superficial cervical flexor muscles such as the SCMs and ASs may be registered during the CCFT. Elevated electromyographic activity, may be a compensation for reduced or impaired activity of the deep cervical flexor muscles in subjects with pain compared to healthy individuals.

Evaluation of the cervical dysfunction in patients with TMD has only been subjectively evaluated through a general clinical examination of the cervical spine (signs and symptoms). Thus, an objective evaluation of motor activity of the cervical muscles through electromyographic (EMG) assessment looking at performance patterns of the cervical musculature activity in patients with TMD could clarify the role of the cervical muscles involvement in the symptomatology of patients with TMD. Additionally, this evaluation could open an area of study to treat these alterations through improvement in motor control of cervical muscles in patients with TMD.

CCFT, as mentioned above, was specifically designed to isolate the activation of deep flexor muscles and identify possible co-contraction patterns of superficial muscles in the cervical spine.[37-39] The construct validity[40, 41] and reliability[42] of the CCFT has been established. However, more advanced psychometric properties such as responsiveness and concurrent validity of this test with clinical variables such as neck disability and pain intensity need to be investigated.

9.2 OBJECTIVES

1. The main objective of this study was to determine, through electromyographic evaluation, whether patients with myogenous TMD and mixed TMD had altered muscular activity on the superficial cervical muscles (sternocleidomastoids and anterior scalenes) expressed in a higher electromyographic activity when executing the craniocervical flexion test compared to normal control subjects. The secondary objectives of this study were:

2. To determine, through electromyographic evaluation, whether patients with mixed TMD had higher muscular activity in the superficial cervical muscles (i.e. sternocleidomastoids and anterior scalenes) when doing the craniocervical flexion test compared to subjects with myogenous TMD.

3. To determine if there was an association between the performance of the cervical flexor muscles while performing the 5 stages of the CCFT and neck disability;

4. To determine if there was an association between the performance of the cervical flexor muscles while performing the 5 stages of the CCFT and jaw disability;

5. To determine if there was an association between level of chronic disability of TMD based on the RDC/TMD (Chronic Pain Grade), pain intensity, duration of complaint, and the performance of the cervical flexor muscles while performing the 5 stages of the CCFT.

9.3 RESEARCH HYPOTHESES

The following hypotheses were investigated in this study:

1. Patients with myogenous TMD and mixed TMD will have altered muscular activity of the superficial cervical muscles (sternocleidomastoids and anterior scalenes) expressed as higher electromyographic activity when executing the craniocervical flexion test compared to normal control subjects.

2. Patients with mixed TMD will have higher muscular activity in the superficial cervical muscles (i.e. sternocleidomastoids and anterior scalenes) when doing the craniocervical flexion test compared to subjects with myogenous TMD.

3. There will be a strong association between the performance of the cervical flexor muscles while performing the 5 stages of the CCFT and neck disability;

4. There will be a strong association between the performance of the cervical flexor muscles while performing the 5 stages of the CCFT and jaw disability;

5. There will be a strong association between level of chronic disability of TMD based on the RDC/TMD (Chronic Pain Grade), pain intensity, duration of complaint, and the performance of the cervical flexor muscles while performing the 5 stages of the CCFT.

9.4 METHODS

9.4.1 SUBJECTS

A convenience sample of subjects who attended the TMD/Orofacial Pain clinic at the School of Dentistry, Faculty of Medicine and Dentistry, University of Alberta and healthy students and staff at the University of Alberta was recruited for this study using advertising in different faculties and surrounding areas (appendix 1). The sample size for this study was calculated based on repeated measures ANOVA test following the guidelines established by Stevens (using α= 0.05 and β= 0.20 power = 80%, and effect size = 0.57).[43] A minimum of 40 subjects per group was needed.

The same inclusion/exclusion criteria for healthy as well as subjects with TMD described in Chapter 3 are applicable to this study

9.4.2 CLINICAL ASSESSMENT

Subjects underwent a clinical examination by a physical therapist with 14 years of experience in musculoskeletal rehabilitation and treatment of temporomandibular disorders (principal investigator) to determine if they met the inclusion criteria or were excluded by the exclusion criteria for this study. Clinical examination followed the guidelines of the diagnostic research criteria for TMD.[44] Briefly, subjects were examined for pain in masticatory muscles, TMJ joint, and also TMJ range of motion (Appendices 2 and 3).

If the physical therapist felt the subject did not meet the inclusion criteria, the subject was excluded from the study. Subjects were asked to read an information letter (appendix 4) and signed an informed consent in accordance with the University of Alberta‘s policies on research using human subjects (appendix 5).

9.4.3 PROCEDURES

9.4.3.1 General Considerations

Demographic data were collected on all subjects who satisfied the inclusion criteria including age, weight, and height. In addition, all subjects were asked to report specific characteristics regarding their jaw problem (i.e. onset, duration of symptoms, treatments received). All subjects were asked also to report their intensity of pain in the jaw (VAS), [45-49] and also complete the Neck Disability Index (NDI) (appendix 6), [50, 51] the Jaw Function Scale (LDF-TMDQ/JFS) (appendix 7),[52] and a history questionnaire for jaw pain used by the RDC/TMD (appendix 8).[44] In addition, the subjects were asked to complete the Chronic Pain Grade Disability Questionnaire for TMD used by the RDC/TMD to evaluate the level of chronic disability due to TMD (appendix 9).[44] These tools have been described previously in Chapter 3.

9.4.4 ELECTROMYOGRAPHIC EVALUATION OF THE CERVICAL FLEXOR MUSCLES

9.4.4.1 Cervical Muscles and Reference Electrode Placement

9.4.4.1.1 Skin Preparation

Each subject's skin was carefully prepared. Prior to the electrode application, the subject's skin was cleaned with alcohol and shaved when necessary to reduce the skin impedance and the electrodes were located following the guidelines for electrodes position describe below.[37, 53]

9.4.4.1.2 Electrode Placement

9.4.4.1.2.1 Superficial Cervical Muscles

For the superficial muscles, electrodes were located on the sternal head of sternocleidomastoid (SCM) and on the anterior scalenes as described in the protocol used by Falla et al.[37, 53]

9.4.4.1.2.2 Reference Electrode

A reference electrode was placed on the wrist. It was held in place by a disposable adhesive patch (for each subject) during the experimental procedure.

9.4.4.2 Normalization Procedure for EMG Data

For normalization purposes, before commencing the collection of experimental data, EMG data was collected for 5 seconds during a maximal voluntary contraction (MVC). The EMG activity of the sternocleidomastoid and scalene muscles was recorded during this maximal contraction and saved in the computer. This procedure was repeated one more time. Submaximal contractions obtained during the craniocervical flexion test (CCFT) were normalized using these 2 maximal MVC values. Submaximal contractions were expressed as a percentage of the 3-second Root Mean Square (RMS) value obtained during the MVC. The average between the normalized contractions using the two MVC maximal measurements was used for statistical analysis.

9.4.4.3 EMG Data Processing

Muscular activity of the sternocleidomastoids (SCMs), anterior scalenus (ASs) was obtained using Bagnoli-8 EMG System (http://www.delsys.com) (appendix 12) in a bipolar configuration with DE-2.1 Electrodes (http://www.delsys.com) (appendix 13). This system is designed to make the acquisition of EMG signals easy and reliable (CMRR: 92 Db, system noise:< 1.2 μV (rms)). The activity of the SCMs and ASs was recorded (analog raw signal) with a data acquisition program, written in Labview 7.1 (National Instruments Inc. Austin, TX) which collected data at 1024 Hz using a PCMCIA card (USB/PCMCIA Cable Strain Relief for laptop and NI USB-6210 Bus-Powered M Series with Signal Express LE, National Instruments Inc. Austin Texas), filtered between 20-450/Hz ±10%, and amplified using a gain of 1000 according to the established standards for EMG acquisition and reporting.[54, 55] Data were saved to a disc for further analysis. To obtain a measure of EMG amplitude, maximum root mean square (RMS) was calculated for 4 seconds during the contraction for each muscle (SCMs and ASs) while doing the CCFT using IGOR Pro5.1 (http://www.wavemetrics.com/index.html) and was expressed as a percentage of the 3 sec EMG activity obtained during the MVC normalization procedure.

9.4.5 PROCEDURE

9.4.5.1 Craniocervical Flexion Test

9.4.5.1.1 Subject Position

Before testing began, subjects were asked to perform a warm up, which consisted of two movements of the neck and head in all directions (flexion, extension, side flexion, and rotation). The subjects were placed in a relaxed supine position with the knees flexed and the head and neck maintained in a mid-position (i.e. neutral position, no flexion or extension) following the protocol established previously.[41] The head and chin were parallel to the plinth (Figure 9-1).

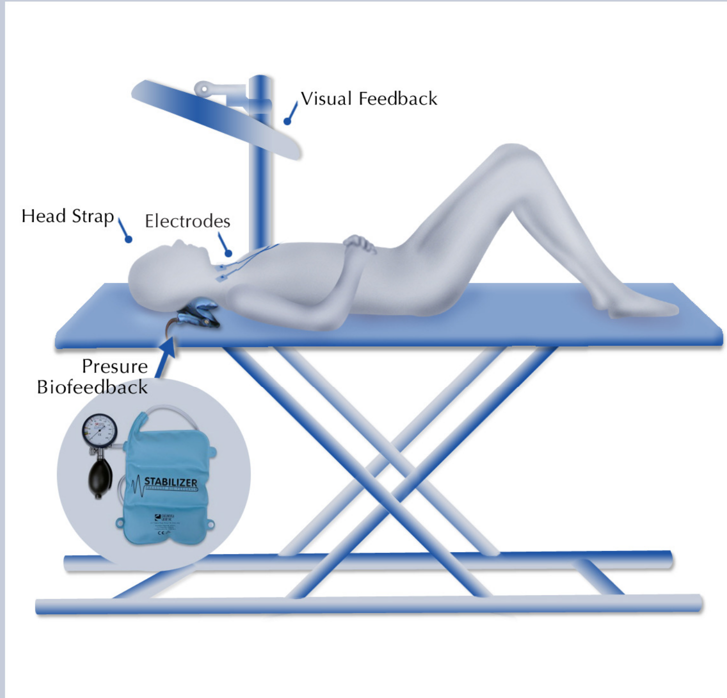


Figure 9-1. Craniocervical Flexion Test (CCFT).

9.4.5.1.2 Craniocervical Flexion Test, Description and Procedures

The CCFT was performed using an air filled pressure sensor which was inserted between the testing surface and the back of the neck (appendix 14). This air pressure sensor was pre-inflated to 20 mm Hg to fill the space without pushing the neck into lordosis. As explained previously, the longus capitis muscles perform the craniocervical flexion movement and a contraction of the longus colli causes a subtle flattening of the cervical lordosis. Thus, the pressure sensor will detect this flattening of the cervical lordosis as a pressure increase. Any unwanted lifting of the head or general cervical flexion will result in the weight of the neck coming off the sensor causing a decrease of the pressure.

Subjects were instructed to perform a gentle nodding movement (craniocervical flexion) and practiced progressive targeted pressure levels using the air filled pressure sensor. Subjects had to practice the test and any neck retraction was identified and discouraged until the subjects could perform the desired movement. Subjects had a 30 second rest period between each targeted pressure so that the head and neck position could be checked and then returned to the starting position.

The CCFT required each subject to perform the craniocervical flexion movement in five progressive stages with the aid of visual feedback device between 22 and 30 mmHg. The order of the targeted pressure level was randomized by an independent assessor. Subjects had to maintain a steady pressure at each targeted level for a duration of 10 seconds (i.e. 22mmHg, 24mmHg, 26mmHg, 28mmHg, and 30mmHg). A visual feedback device was located in front of the subject’s eyes, so the subject could see when she has reached and maintained the desired level. A linear relationship between pressure output and load on the pressure sensor has been demonstrated and it is evident in normal subjects.[41] (Figure 9-1)

The subjects repeated this procedure 2 times for each targeted level with a rest period of 1 minute between each repetition to avoid the effects of fatigue.[56]

9.4.5.1.3 Instrumentation for Registering the Pressure Exerted while Performing the CCFT

An air-filled pressure sensor (pressure biofeedback unit, Chattanooga group, Hixon, TN) (appendix 14) was placed suboccipitally behind the neck of the patients and inflated to a pressure of 20mmHg. The cuff was connected to a pressure transducer (miniature pressure cell, FPN-07PG Fujikura Ltd., Japan) (appendix 15) designed to register increases in pressure with the movement of nodding action for the craniocervical flexion test. Electrical signals from the pressure transducer were amplified to a visual feedback device and projected on a computer screen, so subjects were able to see the targeted pressure level. Graphs with the performance of each subject during the CCFT were stored using Igor Pro5.1. These data were analyzed offline by a blinded assessor.

9.5 ANALYSIS

The normalized data on the EMG activity of all muscles were analyzed descriptively (i.e. mean, standard deviation). A paired “t” test was performed to see if there were any differences between right and left sides in each pair of muscles (the sternocleidomastoid, scalenes). Since there were statistically significant differences between right and left sides of the muscles, both right and left sides were used separately in the analysis.

Variables were tested for normality, homogeneity of variance and linearity. According to the Q-Q plots, all EMG variables were reasonably normally distributed. Histograms and box plots showed that most of the variables were slightly skewed to the right. However, ANOVA analysis is robust to these mild deviations from normality and can provide accurate estimates of the analyzed variables.[57]

A three–way mixed design ANOVA with repeated measures (3 independent variables: muscles [SCM, and scalenes], test [5 levels] and groups [control and TMD patients-between subjects]) test was used to evaluate the differences in EMG activity for selected muscles (dependent variable) while performing the craniocervical test at five levels of presssure. Pair wise comparisons using Bonferroni procedure were administered to evaluate the differences between variables and groups (i.e. control and 2 patient groups) in all of the different conditions (objectives 1 and 2). Spearman rho test was used to evaluate the relationship among Neck Disability Index (NDI), Jaw Function Scale (JFS), and clinical variables with EMG variables (correlational matrix) (objectives 3, 4, and 5). The correlation was considered important when the correlation coefficient value was higher than 0.70. The reference values to make this decision were based on values reported by Munro.[58]

Clinical importance was assessed using the distribution-based method.[59] The effect size (ES) (cohen d) values were calculated to determine clinical importance of the differences in the electromyographic measurements across different levels of pressure and groups.[60] Effect size was considered important when $ES \geq 0.4$.[61] The level of significance was set at $\alpha = 0.05$. SPSS version 17 and STATA version 10 statistical programs were used to perform the statistical analyzed. The analysis was performed blinded to group condition.

9.6 RESULTS

9.6.1 SUBJECTS

A total number of 168 subjects were assessed for inclusion in this study. A total of 18 subjects were excluded. The main reasons for exclusion were: not totally healthy (9 subjects), older than 50 years old (2 subjects), having a neurological disease (1 subject), having cancer (1 subject), or the pain score was lower than 30 mm on the visual analogue scale (5 subjects). One hundred and fifty participants (150) provided data for this study. Of the 150 subjects, 47 subjects were healthy, 54 subjects had myogenous temporomandibular disorders (TMD) and 49 subjects had mixed TMD.

9.6.2 SAMPLE CHARACTERISTICS

The general demographics for each group are as follows (Table 9-1):

Table 9-1. Descriptive Statistics of Height, Weight, and Age for all Subjects by Group (Myogenous TMD, Mixed TMD, and Healthy).

	condition	Mean	Std. Deviation	N
Height (cm)	Myogenous TMD	165.09	5.10	54
	Healthy	165.05	6.76	47
	Mixed TMD	166.26	5.86	49
Weight (Kg)	Myogenous TMD	64.07†	9.92	54
	Healthy	64.32†	12.68	47
	Mixed TMD	72.12*	15.87	49
Age (years)	Myogenous TMD	31.35	8.97	54
	Healthy	28.26	7.46	47
	Mixed TMD	31.27	8.27	49

*** Significantly different when compared with healthy subjects at α=0.05**
† Significantly different when compared with subjects with mixed TMD at α=0.05

The clinical characteristics of the participants are displayed in Table 9-2. There were no significant differences in the sample in age and height. However, weight was significantly different between subjects with mixed TMD and myogenous TMD (mean difference 8.05 kg [95%CI 1.856, 14.244] p=0.006) and between subjects with mixed TMD and healthy subjects (mean difference 7.80 kg [95%CI 1.387, 14.206] p=0.011). No weight differences were found between healthy subjects and subjects with myogenous TMD.

Table 9-2. Clinical Characteristics for all Subjects by Group (i.e. Myogenous TMD, Mixed TMD, and Healthy).

Duration of complaint (years)	**Myogenous TMD**	**6.54***	**6.46**	54
	Healthy	**0.00**	**0.00**	47
	Mixed TMD	**8.29***	**6.38**	49
Pain Intensity (0-100 mm)	**Myogenous TMD**	**45.28***	**17.31**	54
	Healthy	**0.00**	**0.00**	47
	Mixed TMD	**48.98***	**16.054**	49
Neck Disability Index (0-50 points)	**Myogenous TMD**	**10.46***	**5.545**	54
	Healthy	**1.55**	**1.572**	47
	Mixed TMD	**12.60***	**6.838**	49
Jaw Function Scale (10-50 points)	**Myogenous TMD**	**18.57*†**	**6.566**	54
	Healthy	**10.13**	**.397**	47
	Mixed TMD	**22.71***	**7.113**	**49**

*** Significantly different when compared with healthy subjects at α=0.05**
† Significantly different when compared with subjects with mixed TMD at α=0.05

Subjects with TMD (mixed and myogenous) were significantly different from healthy subjects in all symptom characteristics (i.e. pain intensity, duration of complaint, NDI Score and JDI Score) ($p<0.05$). Subjects with mixed TMD were similar to subjects with myogenous TMD in most of the general characteristics such as duration of complaint and pain intensity ($p>0.05$). The average pain intensity on VAS scale for patients with myogenous TMD was 45.28 mm and 48.98 mm for subjects with mixed TMD. Regarding duration of complaint, most of the patients had a long history of pain with an average of 8.3 years of pain for subjects with mixed TMD and an average of 6.5 years for subjects with myogenous TMD (not significantly different between groups , $p>0.05$).

Related to the level of dysfunction of the subjects with TMD, both groups did not present with a high level of dysfunction either in the neck or in the jaw. The maximum score for the Neck Disability Index was 50, and the subjects having mixed TMD only had an average of 12.60 points and the subjects with myogenous TMD had 10.46 points. Both values are considered only mild neck disability.[57, 59]. For the Jaw Function Scale, the maximum score was 50 points and the average obtained by the subjects with mixed TMD was 22.71 and only 18.57 for the subjects with myogenous TMD. Based on these two scales, the severity for both types of dysfunction in this sample of patients was not severe.

The Jaw Dysfunction Score was significantly higher for subjects with mixed TMD compared to myogenous TMD subjects (mean difference 4.13 points, p=0.001 [95%CI 1.42, 6.85]). Neck Disability Scores were not significantly different between subjects with mixed TMD when compared with myogneous TMD, however, subjects with mixed TMD presented with a higher disability score, although not significant, than the subjects with myogenous TMD (p>0.05).

9.6.3 EMG Activity of the Cervical Flexors Muscles while Performing the CCFT

A large variability of the normalized EMG activity across conditions and groups was observed (Figure 9-2). Using a three–way mixed design ANOVA with repeated measures analysis, it was found that the main effects of muscles (F=18.531 p=0.0001) and pressure levels (F=27.275 p=0.0001) were statistically significant. This means that there was a statistically significant difference in EMG activity among muscles and also among pressure levels. The interaction between muscles and pressure was also statistically significant (F=2.891 p=0.001). The remaining main effects and interactions were not statistically significant (Table 9-3). In addition, there was a marginal but not significant difference between groups in the analyzed variables (F=2.592, p=0.078).

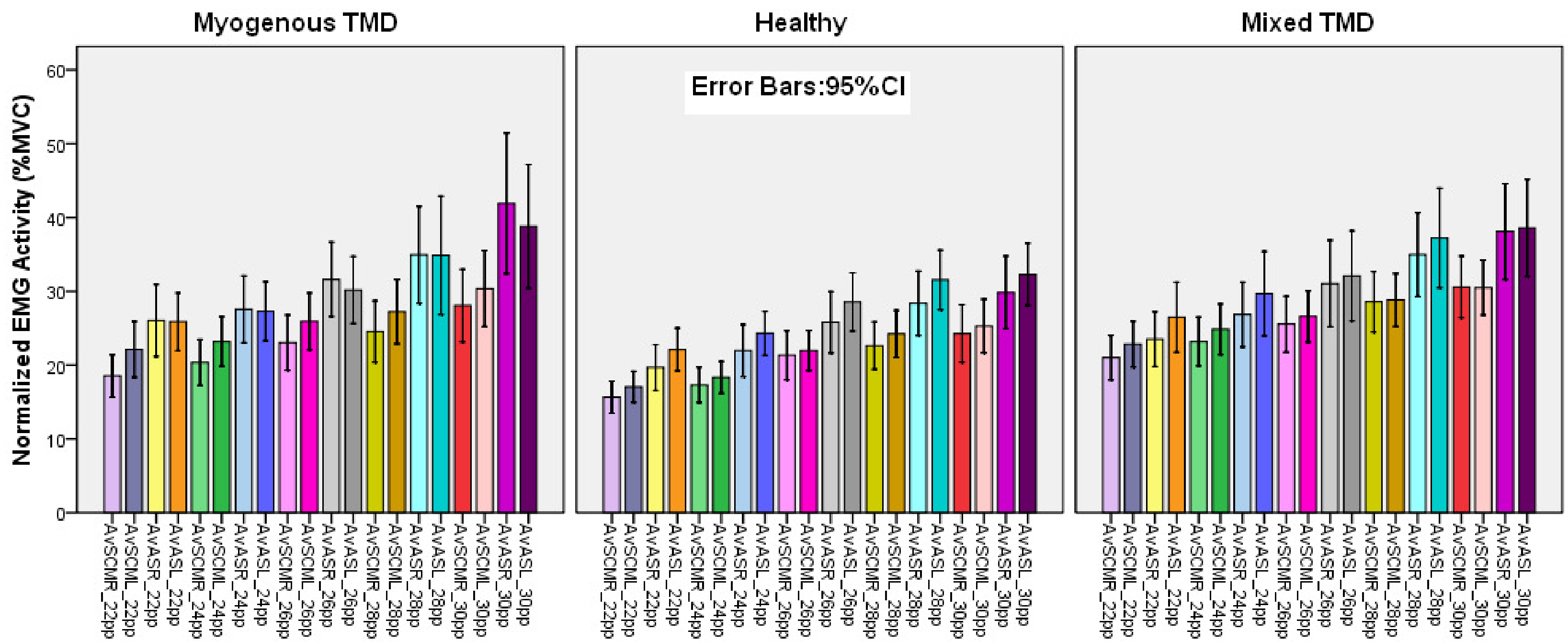
Table 9-3. Multivariate Analysis Results.

Effect	test	Value	F	Hypothesis df	Error df	Sig.
Muscle (type of)	Wilks' Lambda	0.723	18.531[a]	3.000	145.000	0.00*
muscle * Group (TMD type and healthy)	Wilks' Lambda	0.963	0.917[a]	6.000	290.000	0.48
Pressure (levels of pressure)	Wilks' Lambda	0.569	27.275[a]	4.000	144.000	0.01*
Pressure * Group	Wilks' Lambda	0.952	0.891[a]	8.000	288.000	0.52
Muscle * Pressure	Wilks' Lambda	0.797	2.891[a]	12.000	136.000	0.01*
Muscle * Pressure * Group	Wilks' Lambda	0.894	0.651[a]	24.000	272.000	0.90

*** Significant at α=0.05**

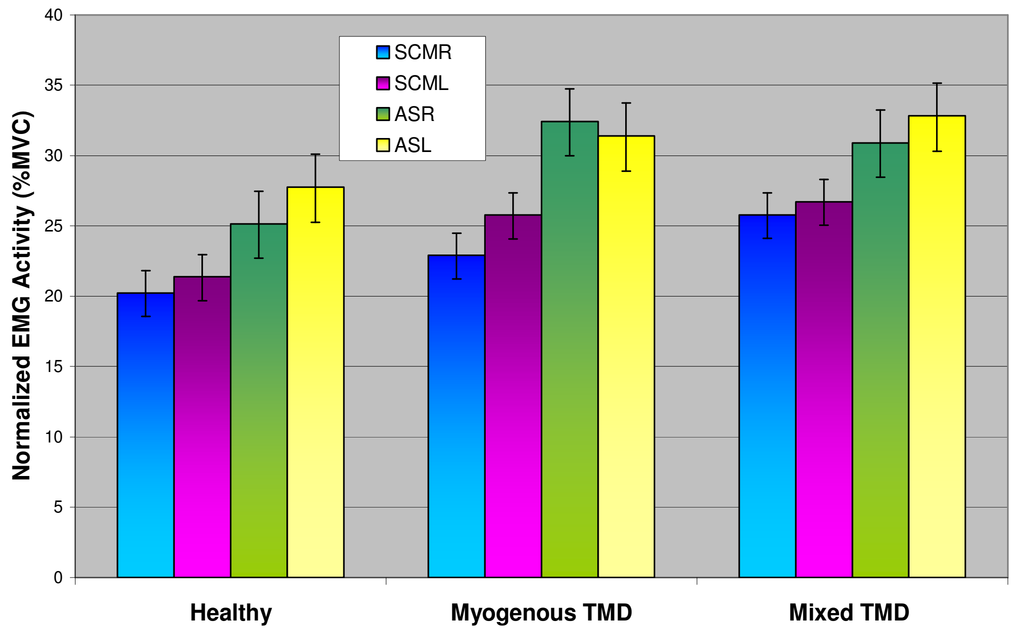
Electromyographic activity (EMG) was significantly different across muscles and pressure levels regardless of group. Post hoc tests showed that both SCM muscles (right and left) had a significantly lower activity than both AS muscles (right and left) regardless of level of pressure or group (p<0.05) (Figure 9-3).The EMG activity increased from 22 mmHg to 30 mmHg regardless the group or muscle analyzed. The lowest level of pressure (22mmHg) had the smallest electromyographic activity and the highest level of pressure (30mHg) had the highest electromyographic activity (Figure 9-4). All levels of pressure were significantly different among each other (p<0.05). The electromyographic activity increased proportionally with the increase in the level of pressure. This relationship has also been found in previous research.[37, 39, 62]

Figure 9-2. Normalized EMG Activity of SCM and AS Muscles in Subjects with Myogenous TMD, Mixed TMD, and Healthy Subjects when Executing the Craniocervical Flexion Test



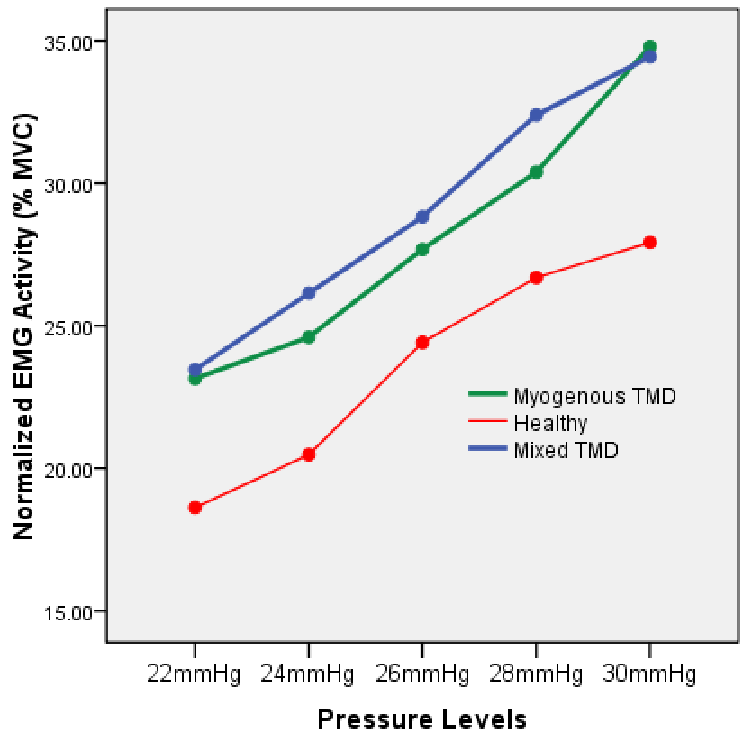
AvSCMR_22pp: Sternocleidomastoid Right electromyographic activity at 22mmHg; AvSCML_22pp: Sternocleidomastoid Left electromyographic activity at 22mmHg; AvASR_22pp: Anterior Scalene Right electromyographic activity at 22mmHg; AvASL_22pp: Anterior Scalene Left electromyographic activity at 22mmHg; AvSCMR_24pp: Sternocleidomastoid Right electromyographic activity at 24mmHg; AvSCML_24pp: Sternocleidomastoid Left electromyographic activity at 24mmHg; AvASR_24pp: Anterior Scalene Right electromyographic activity at 24mmHg; AvASL_24pp: Anterior Scalene Left electromyographic activity at 24mmHg; AvSCMR_26pp: Sternocleidomastoid Right electromyographic activity at 26mmHg; AvSCML_26pp: Sternocleidomastoid Left electromyographic activity at 26mmHg; AvASR_26pp: Anterior Scalene Right electromyographic activity at 26mmHg; AvASL_26pp: Anterior Scalene Left electromyographic activity at 26mmHg; AvSCMR_28pp: Sternocleidomastoid Right electromyographic activity at 28mmHg; AvSCML_28pp: Sternocleidomastoid Left electromyographic activity at 28mmHg; AvASR_28pp: Anterior Scalene Right electromyographic activity at 28mmHg; AvASL_28pp: Anterior Scalene Left electromyographic activity at 28mmHg; AvSCMR_30pp: Sternocleidomastoid Right electromyographic activity at 30mmHg; AvSCML_30pp: Sternocleidomastoid Left electromyographic activity at 30mmHg; AvASR_30pp: Anterior Scalene Right electromyographic activity at 30mmHg; AvASL_30pp: Anterior Scalene Left electromyographic activity at 30mmHg

Figure 9-3 Normalized EMG Activity for Sternocleidomastoid and Scalene Muscles by Group



SCMR: Sternocleidomastoid Right
SCML: Sternocleidomastoid Left
ASR: Anterior Scalene Right
ASL: Anterior Scalene Left

Figure 9-4 Normalized EMG Activity by Pressure Levels and Groups



9.6.4 ASSOCIATION BETWEEN EMG VARIABLES WHILE PERFORMING THE CCFT AND CLINICAL VARIABLES

Very weak correlations (although statistically significant) were found, mainly between the EMG activity of the SCM muscles during the 5 stages of the CCFT and clinical variables such as pain intensity, duration of complaint, neck disability, jaw disability, and level of chronic disability of TMD based on the RDC/TMD (Chronic Pain Grade Questionnaire) (Table 9-4).

Table 9-4. Correlations between EMG Activity and Clinical Data.

	NDI	Chronic Pain Grade classification	JDI	Pain Intensity	Duration of complaint (years)
average SCM 22 mmHg	**0.233****	**0.261****	**0.264****	**0.324****	0.153
average AS 22mmHg	**0.128**	**0.145**	**0.146**	**0.210****	0.051
average SCM24mmHg	**0.227****	**0.259****	**0.297****	**0.322****	0.186*
Average AS24mmHg	**0.142**	**0.157**	**0.169***	**0.208***	0.079
Average SCM26mmHg	**0.179***	**0.189***	**0.237****	**0.288****	0.093
Average AS26mmHg	**0.133**	**0.120**	**0.151**	**0.213****	0.037
Average SCM28mmHg	**0.184***	**0.169**	**0.233****	**0.274****	0.127
Average AS 28 mmHg	**0.129**	**0.101**	**0.169***	**0.220****	0.031
Av SCM30 mmHg	**0.240****	**0.214***	**0.283****	**0.325****	0.161*
Av AS30mmHg	0.197*	0.182*	0.222**	0.280**	0.107

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

9.6.5 *Clinical Significance*

Moderate and clinically important effect sizes of comparisons between myogenous TMD and mixed TMD, when compared with healthy subjects while performing the CCFT were found and are displayed in Table 9-5. The findings indicate that the differences among groups were clinically important.[61] However, because of the high variability of the electromyographic activity, mainly in the groups of subjects with pain, these findings did not reach statistical significance.

Table 9-5. Moderate Effect Sizes Found between Comparison Between TMD Patients and Healthy Subjects at Different Levels of Pressure while Performing the Craniocervical Flexion Test.

COMPARISONS	RAW DIFFERENCES			STANDARDIZED EFFECT SIZE			
Outcome measure Electromyographic Activity	Mean Difference	Confidence Interval for Difference		**Effect size**	Confidence Interval for Effect Size		**Effect size based on healthy group standard deviation**
		lower	upper		lower	upper	
Av SCMR at 22mmHg Mixed TMD vs. Healthy	5.36	1.65	9.07	**0.59**	0.17	0.99	**0.73***
Av SCMR at 24mmHg Mixed TMD vs. Healthy	5.88	1.83	9.93	**0.59**	0.18	0.99	**0.72***
Av SCMR at 28mmHg Mixed TMD vs. Healthy	5.94	0.77	11.11	**0.47**	0.06	0.87	**0.54***
Av SCMR at 30mmHg Mixed TMD vs. Healthy	6.31	0.67	11.95	**0.45**	0.04	0.85	**0.48***
Av SCML at 22mmHg Myogenous vs. Healthy	5.10	0.66	9.54	**0.45**	0.06	0.85	**0.72***
Av SCML at 22mmHg Mixed TMD vs Healthy	5.79	2.06	9.52	**0.63**	0.21	1.03	**0.82***
Av SCML at 24 mmHg Myogenous vs. Healthy	4.87	0.79	8.95	**0.47**	0.07	0.87	**0.66***
Av SCML at 24mmHg Mixed TMD vs. Healthy	6.53	2.49	10.57	**0.66**	0.24	1.06	**0.89***
Av SCML at 26mmHg Mixed TMD vs. Healthy	4.63	0.25	9.01	**0.43**	0.02	0.83	**0.50***
Av SCML at 30mmHg Mixed TMD vs. Healthy	5.19	0.06	10.32	**0.41**	0.00	0.81	**0.42***
Av ASR at 22 mmHg Myogenous vs. Healthy	6.39	0.49	12.29	**0.43**	0.03	0.82	**0.60***
Av ASR at 30mmHg Myogenous vs. Healthy	12.07	1.02	23.12	**0.43**	0.03	0.82	**0.72***
Av ASR at 30mmHg Mixed TMD vs. Healthy	8.24	0.17	16.31	**0.41**	0.01	0.81	**0.49***

SCMR: Sternocleidomastoid right
SCML: Sternocleidomastoid left
ASR: Anterior scalene right
***Clinically significant**

9.7 DISCUSSION

The main finding of this study was that there was no statistically significant difference in electromyographic activity in sternocleidomastoid muscles nor the anterior scalene muscles in patients with TMD when compared to healthy subject while performing the craniocervical flexion test. Thus, these results do not support the first and second hypotheses of this study. However, clinical important effect sizes were found. In addition, only weak correlations between the EMG variables and clinical variables such as pain intensity, jaw disability, and neck disability were found rejecting the remaining hypotheses (3^{rd}, 4^{th}, and 5^{th} hypotheses) stated by this study.

The results of this study cannot be compared with other studies investigating cervical flexor muscle performance in patients with TMD since no studies were found. Thus, this study adds to the knowledge in this area.

CCFT has widely been used in cervical disorders such as neck pain, whiplash associated disorders (WAD) and cervicogenic headache to determine alterations in the motor control of the craniocervical flexor muscles since it is thought that impairment of the deep flexor muscles appear to be generic to neck disorders.[32] Thus, these studies will be used as comparison of this study.

Falla et al.,[37] using a novel technique for evaluating the deep flexor muscles, found that patients with neck pain had significant alterations in the pattern of contraction of the deep and superficial flexor muscles when performing the craniocervical flexion test. Deep flexor muscles showed a decreased activity when performing the CCFT in patients with neck pain compared with healthy subjects. In addition, sternocleidomastoid (SCM) and anterior scalene (AS) muscles showed higher levels of normalized EMG activity than normal subjects when performing the craniocervical flexion test. Jull,[38] and Jull et al.,[39] also evaluated the EMG activity of the SCM muscle while performing the CCFT in subjects with WAD and healthy subjects and patients with whiplash, subjects with insidious onset of neck pain, and control subjects respectively. The results of Jull and Jull et al.,[39] confirmed the results of Falla et al.[37] The SCM muscle was found to have an increased EMG in subjects with WAD, and in subjects with insidious onset of neck pain relative to the healthy controls. Chiu et al.,[63] using a clinical CCFT found similar results. Patients with chronic neck pain were unable to hold a high level of pressure when compared with healthy subjects (28mmHg vs. 24 mmHg).

Furthermore, a systematic review investigating the physical impairments in patients with cervicogenic headache[64] revealed similar results. Jull et al.[65] found that patients with CEH had a reduced activation score (SMD:-1.86 [95% CI -2.74, 0.99]) as well as a reduced performance index (SMD: -1.08 [95% CI -1.85, 0.31] when compared with normal subjects. Zito et al.[66] found that patients with CEH presented higher normalized electromyographic activities of sternocleidomastoid than the control group; however the differences were not statistically significant. Fernandez de las Penas et al.,[67] also found an impaired function of the cervical flexor muscles in a group of patients with chronic tension type headache.

Thus, all of the studies analyzing craniocervical performance using CCFT converge in that patients with chronic neck pain have an impaired performance of the deep and superficial flexor cervical muscles. This impairment in the craniocervical test may be linked to an altered performance of the deep cervical flexor muscles and increased activity in superficial neck flexors (SCM and scalenes). This increased activity in the superficial muscles can be seen as a strategy to compensate for the dysfunction of the deep flexor muscles. As mentioned previously, Sterling[68] has suggested that the presence of pain could lead to inhibition or delayed activation of specific muscles or group of muscles in the spine. This inhibition generally occurs in deep muscles such as the longus colli and longus capitis which control joint stability.[68]

Although these papers offer a promising clinical application of their findings, unfortunately the quality of the majority of these studies was poor. Most of the studies lacked adequate sample size, good control of confounders, and blinding of outcomes measures. All of these flaws make the generalizability of the results more difficult.

The results of this study are not in agreement, in part, with the majority of the above mentioned studies. The present study found no significant differences among groups in superficial cervical flexor muscular activity while performing the CCFT evaluated though electromyographic analysis. One possible explanation for these results could be the level of dysfunction presented by the subjects with TMD. It was found that the level of dysfunction, not only at the level of the neck but also at the level of the jaw, was considered mild for subjects with TMD. Most of the studies investigating the performance of the cervical flexor muscles while performing the CCFT in patients with neck pain did not provide the level of disability of the neck of their samples which make their results difficult to compare with ours. The level of disability was only reported by one study.[37] Their results are in agreement with the results obtained in the present study with subjects having similar level of disability as the subjects participating in this present study (NDI 12.4±9.5 points[37] and NDI: 10.46± 5.55 for myogenous TMD and NDI; 12.60±6.84 for subjects with mixed TMD respectively). Thus, the severity of dysfunction could have an influence on muscular performance of the cervical flexor muscles. Falla et al,[37], examined the EMG from the superficial (i.e. sternocleidomastoid and scalene) and deep cervical muscles (i.e. longus colli and longus capitis) in a group of 10 chronic neck pain patients and 10 controls while performing the craniocervical test. They found that even though the normalized EMG amplitude of the deep cervical flexor muscles was significantly lower in patients with neck pain when compared with healthy subjects ($p<0.05$), the increase of the EMG activity of the superficial muscles did not reach statistical significance, although there was an important trend of increased EMG activity for the superficial muscles (SCM and AS) in patients with neck pain when compared with healthy controls,. The main explanation of this finding was the large variability of the EMG activity found across subjects and conditions. These results agree with our findings. The mean EMG activity of the superficial muscles was always higher for subjects with pain when compared with healthy subjects across all condition and muscles (Fig 9-2). However, the large variability of the normalized EMG activity between subjects and groups impaired the possibility of finding a statistical significance.

The great variability obtained of the electromyograpic activity of the cervical flexor muscles also has been observed in other regions such as the low back.[69] Hodges et al.,[69] found that subjects responded differently to experimental pain in the low back muscles. They reported that no two subjects showed identical patterns of increased activity of the low back muscles when they underwent experimental pain. If this phenomenon was extrapolated to the cervical spine, it could be speculated that each subject has a different strategy to adapt to pain. Therefore, the motor response in the cervical spine, in many of the cases of people with pain, would be an increase of the activity of the SCMs and AS muscles; however other strategies, using different muscles not investigated in this research, could also be present. Further research investigating possible motor strategies in people with TMD under different conditions would clarify the role of the cervical muscles in TMD.

Another similarity between Falla et al.'s[37] study and the present study, as mentioned above, was that the level of neck disability present in their subjects. Thus, it could be plausible to speculate that because of the level of disability was mild, it did not have an impact on function or physical impairments generally found in subjects with more disabling pain. Further research looking at subjects with more severe levels of dysfunction and different types of TMD are needed in order to determine if these muscular impairments would be present in more severe and disabling cases.

This study did not measure directly the activity of the deep cervical flexor muscles because the technique to measure the activity of the deep cervical muscles is invasive and compliance with the testing protocol would have been impaired. We only measured the superficial cervical muscles such as the SCM and AS as an indirect measure of impairment of the activity of the deep cervical flexor muscles. Based on previous studies,[32, 40-42, 62, 70, 71] the superficial muscles (i.e. SCM and AS) are not the prime movers in a CCFT and thus should not show large electromyographic activity during the test. The increased activity of the superficial cervical flexor muscles was believed to be a strategy to compensate for a decreased activity of the deep cervical flexor muscles to stabilize the cervical spine and facilitate the movement. Thus, it is still uncertain if deep cervical muscles activity was impaired in these patients. In addition, since cervical spine is a very complex system which is characterized for a high degree of redundancy in the muscular system,[31, 72] it is not surprising that other motor strategies and other muscles not analyzed in this study (instead of SCM and AS) could be used by subjects with pain to stabilize the cervical spine. More research involving the study of other muscle groups in this population is warranted.

CCFT has been considered a gold standard to isolate the activation of deep flexor muscles and identify possible co-contraction patterns of superficial muscles in the cervical spine.[37-39] Its construct validity [40, 41] as well as its reliability,[42] have been established, however, more advanced psychometric properties such as responsiveness and concurrent validity with clinical variables such as neck disability and pain intensity of this test need to be ascertained. Thus, this study investigated the associations between the muscular activities of the analyzed muscles through the 5 stages of the CCFT with clinical variables such as the level of chronic pain grade classification of TMD based on the RDC/TM, pain intensity, time of complaint, jaw disability and neck disability. Most of the associations were positive but weak, indicating that the performance of the CCFT is not strongly related with other clinical variables such as pain intensity or neck or jaw disability. These results are in agreement with those found by Falla et al. [73] who reported that reduction in pain in patients with neck pain after a training program was not accompanied by an improvement of the performance of the cervical flexor muscles. It seems that pain and physical performance of the craniocervical muscles are representing different aspects of disability in subjects with cervical involvement. In addition, disability is a multifaceted concept that depends not only on physical factors but also on psychological factors. It has been suggested that pain-related beliefs such as self-efficacy are important determinants of disability in patients with musculoskeletal pain.[74] The physical performance of the cervical flexor muscles could be just a part of the whole concept of disability, however, it cannot be considered as a direct measure of disability.

Because of the variability of the results found in the electromyograpic activity among groups and conditions, an analysis of the clinical significance of the results was conducted in order to evaluate the relevance of these findings. According to Musselman,[59] effect size calculation is one of the most common ways to evaluate clinical significance after the fact. It is recognized that effect sizes of 0.20, 0.5 and 0.8 correspond to small, moderate and large effect sizes respectively.[61] Based on this consideration, many important effect sizes were found between some of the comparisons between subjects with mixed and myogenous TMD when compared with healthy subjects (Table 9-4). The effect sizes ranged between 0.41 and 0.66. This range indicates that although no statistically significant differences were found due to the large data variability, clinical significant differences between subjects with TMD and healthy subjects in these conditions were found. This is of importance for clinicians who work in this field, since this analysis indicates that subjects with pain tended to have increased activity of the superficial cervical muscles, especially subjects with mixed TMD, when compared with healthy subjects. This shows a change in the strategy of the cervical muscles to control the cervical spine in subjects with TMD. Therefore, these results should be considered when treating patients with TMD. Future research should look at implementing exercises that address these cervical impairments and test their effectiveness in decreasing pain and improving function in patients with TMD.

9.8 CONCLUSION

There were no statistically significant differences (p=0.07) in electromyographic activity in the sternocleidomastoid muscles or the anterior scalene muscles in patients with mixed or myogneous TMD subjects when compared to healthy subjects when performing the craniocervical flexion test. However, clinically significant effect sizes were obtained. Thus, these findings should be taken into consideration when evaluating and treating patients with TMD because there is a strong trend indicating that subjects with TMD appear to have a different muscle strategy for controlling the cervical spine than healthy subjects do. Thus, exercise programs addressing these abnormal motor patterns might be of value when treating these subjects. However, future research should test the effectiveness of this type of program in subjects with TMD in order to determine the real value of treating this type of impairment in these TMD populations.

Associations between EMG activity obtained through the 5 stages of the CCFT and clinical variables such as pain intensity, duration of complaint, neck disability, jaw disability, chronic disability of TMD used by the RDC/TMD, showed positive trends, however, the correlations were weak.

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10 CHAPTER 10

FATIGABILITY OF THE CERVICAL EXTENSOR MUSCLES WHILE DOING THE NECK EXTENSOR MUSCLE ENDURANCE TEST (NEMET) IN PATIENTS WITH TEMPOROMANDIBULAR DISORDERS

10.1 INTRODUCTION

Some clinical evidence of the interconnection between the cervical spine and temporomandibular disorders (TMD) has been demonstrated.[1-5] Experiments using animals have studied the relationship between the craniofacial region and cervical structures. Hellstrom et al.,[6] demonstrated that bradykinin injected into the TMJ, changed the sensitivity of muscle spindles in cervical muscles. In addition, Kobayashi et al.,[7] found that selective stimulation of pressure receptors in the temporomandibular joint (TMJ) capsule, elicited tonic activation of the splenius motor units indicating that TMJ sensory information induces neck muscle activities. Yu et al.[8] found that irritation of the temporomandibular joint (TMJ) caused an increase in the activity of the masticatory muscles (i.e. masseter) as well as increased activity in the cervical muscles (i.e. trapezius and bilateral deep neck muscles (rectus capitis posterior) (although no statistical significant). Based on their findings, the authors of these studies felt that reflex connections between the TMJ nociceptors and mechanoreceptors, and the fusimotor-muscle spindle system of the dorsal neck muscles might be involved in the pathophysiological mechanisms responsible for the sensory-motor disturbances in the neck region found in TMD patients.

Findings from clinical studies have also supported the connection between cervical spine and orofacial region. Fricton et al.[9] described the pain patterns of 164 patients diagnosed with cervical myofascial pain syndrome (MFPS) and they realized that cervical muscles could cause pain in the cranial and facial region. In addition, Carlson et al.[10] found in a group of patients with MFPS that injection on the trigger point (TP) of the upper trapezius caused a decrease in the pain felt in the masseter muscle and a decrease in its EMG activity. Furthermore, Svennson et al.,[11] investigated the motor behavior of the sternocleidomastoid (SCM), splenius capitis and masseter muscles during different head positions when glutamate was injected into masseter and splenius capitis. They found that when glutamate was injected into the masseter, the EMG activity of the masseter as well as the activity of the SCM and splenius capitis was increased when the head was in a resting position. Lower cervical intramuscular anesthetic injections have demonstrated good results in relief of symptoms in patients with orofacial pain conditions [12] and intractable head or face pain. [13] Thus, the evidence of these studies indicate that there are anatomical and neurophysiological connections between the orofacial region and the cervical muscles that could explain the overlapping of symptoms between patients with jaw and neck pain.

As mentioned above, some patients with TMD have found to have cervical muscle dysfunction. However, to date the assessment of this cervical dysfunction in patients with TMD has only been subjectively evaluated through a general clinical examination of the cervical spine. More objective measures of cervical muscle function such as strength, endurance, and performance (i.e. measured through the craniocervical flexion test) of the neck muscles have not been performed. Thus, it is still unknown if these muscular function measurements of the cervical muscles could be altered in subjects with TMD.

Endurance of the neck extensor muscles has been considered an important physical variable when evaluating and treating neck impairments in cervical conditions.[14-18] It has been shown that subjects with neck pain presented with a reduced endurance of the neck extensors and flexors when compared with normal subjects.[14-16, 19-23] In addition, good results have been obtained when treating neck endurance impairment in clinical research trials.[17, 18, 22]

The assessment of the endurance of the neck extensor muscles has been performed in different ways and in different populations. [14-16, 24-28] The neck extensor muscle endurance test, which is a modification of the lumbar Biering-Sorensen test,[27, 28] has been one of the tests generally used to measure neck endurance because of its simplicity, good reliability, [25, 29] and the potential use in clinical practice. Although this test has been commonly used in clinical research settings, there is no agreement to date as to the best way to assess neck endurance. In addition, it has not been determined whether the holding time measured through the clinical neck extensor muscle endurance test was associated with myoelectric manifestations of fatigue. Since no information regarding endurance of the neck extensor muscle in subjects with TMD was found in the literature, this study was designed to overcome this lack of knowledge.

10.2 OBJECTIVES

The objectives of this study were:

1. The main objective of this study was to determine through electromyographic evaluation, whether patients with myogenous and mixed TMD have greater fatigability of the cervical extensor muscles (midcervical paraspinal muscles [trapezius, capitis group, and cervicis, group]) when performing a neck extensor muscle endurance test (NEMET) when compared to healthy control subjects. The secondary objective of this study was:

2. To determine whether patients with myogenous and mixed TMD demonstrate greater fatigability of the cervical extensor muscles (midcervical paraspinal muscles [trapezius, capitis group, and cervicis, group]) through the holding time during the neck extensor muscle endurance test (NEMET) when compared to healthy control subjects.

3. To determine if there was an association between holding time with neck disability, jaw disability, pain intensity, and time of complaint.

10.3 RESEARCH HYPOTHESES

The following research hypotheses were investigated in this study:

1. Patients with myogenous and mixed TMD will have greater fatigability of the cervical extensor muscles (midcervical paraspinal muscles [i.e. trapezius, capitis group, and cervicis group]) when performing a neck extensor muscle endurance test (NEMET), evaluated using electromyography, when compared to healthy control subjects.
2. Patients with myogenous and mixed TMD will demonstrate greater fatigability of the cervical extensor muscles (midcervical paraspinal muscles [i.e. trapezius, capitis group, and cervicis groups]) expressed as reduced holding time during the neck extensor muscle endurance test (NEMET) when compared to healthy control subjects.

3. There will be a strong association between holding time of the cervical extensor muscles during the NEMET with neck disability, jaw disability, pain intensity, and time of complaint.

10.4 METHODS

10.4.1 SUBJECTS

A convenience sample of subjects who attended the TMD/Orofacial Pain Clinic in the School of Dentistry, Faculty of Medicine and Dentistry, University of Alberta, and healthy students and staff at the University of Alberta was recruited for this study using advertising in different faculties and surrounding areas. Sample size calculation for this study was based on multiple regression analysis using the guidelines proposed by Stevens (using $\alpha = 0.05$, €= 0.05, population multiple correlation (ρ)=0.25).[30, 31] Based on this calculation, approximately 46 subjects per group were needed for this study.

The same inclusion/exclusion criteria for healthy as well as subjects with TMD described in Chapter 3 are applicable to this study

10.4.2 CLINICAL ASSESSMENT

Subjects underwent a clinical examination by a physical therapist with 14 years of experience in musculoskeletal rehabilitation and treatment of temporomandibular disorders (principal investigator) to determine if they met the inclusion criteria or were excluded by the exclusion criteria for this study. Clinical examination followed the guidelines of the diagnostic research criteria for TMD.[32] Briefly, subjects were examined for pain in masticatory muscles, TMJ joint, and also TMJ range of motion (Appendices 2 and 3).

If the physical therapist felt the subject did not meet the inclusion criteria, the subject was excluded from the study. Subjects were asked to read an information letter (appendix 4) and signed an informed consent in accordance with the University of Alberta‘s policies on research using human subjects (appendix 5).

10.4.3 PROCEDURES

10.4.3.1 General Considerations

Demographic data were collected on all subjects who satisfied the inclusion criteria including age, weight, and height. In addition, all subjects were asked to report specific characteristics regarding their jaw problem (i.e. onset, duration of symptoms, treatments received). All subjects were asked also to report their intensity of pain in the jaw (VAS), [33-37] and also complete the Neck Disability Index (NDI) (appendix 6), [38, 39] the Jaw Function Scale (LDF-TMDQ/JFS) (appendix 7),[40] and a history questionnaire for jaw pain used by the RDC/TMD (appendix 8).[32] These tools have been described previously in Chapter 3.

10.4.4 ELECTRODE POSITION OF CERVICAL MUSCLES AND REFERENTIAL ELECTRODE PLACEMENT.

10.4.4.1 Skin Preparation

The subjects' skin was carefully prepared. Prior to the electrode application, the subjects' skin was cleaned with alcohol and shaved when necessary to reduce its impedance and then the electrodes were located following the guidelines for electrodes position.

10.4.4.2 Electrode Placement

10.4.4.2.1 Cervical extensor Muscles:

For the cervical extensor muscles, the electrodes were located over the distal half of the distance between the base of the occiput and the spinous process of the seventh cervical vertebra as described in the protocol used by Falla et al.[41] and Cram et al.[42] (Figure 10-1).

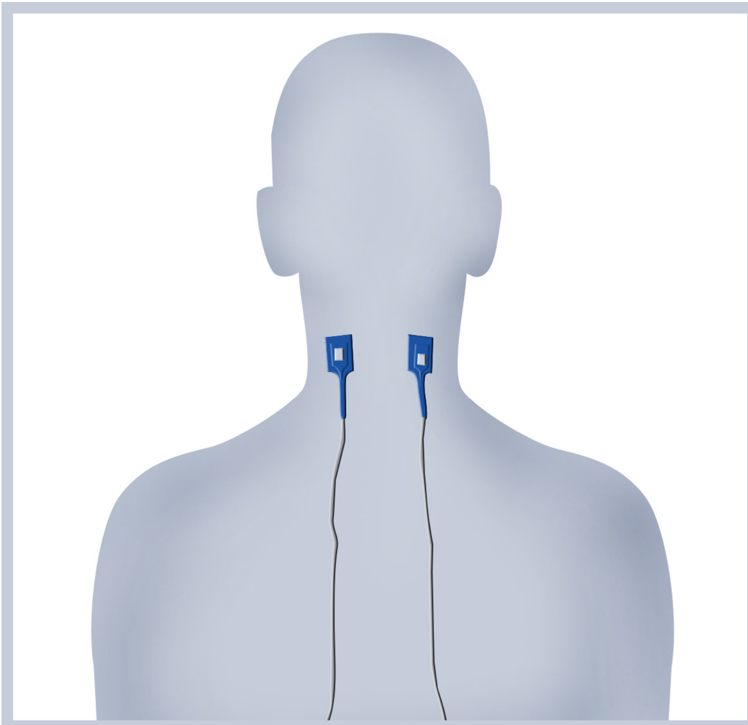


Figure 10-1. Electrodes' Location for the Cervical Extensor Muscles

10.4.4.2.2 Reference Electrode

A referential electrode was placed on the wrist. All electrodes were held in place by an adhesive disposable patch (for each subject) during the experimental procedure.

10.4.5 Procedure

10.4.5.1 Patient position

Before testing started, subjects were asked to perform a warm up, which consisted of two movements of the neck and head in all directions (flexion, extension, lateral inclination, and rotation). Each subject then lay in prone on a plinth with their head and neck initially supported over the end of the plinth with the arms alongside their trunk. Straps were placed across the T2 level in order to counter support the thoracic spine, at the level of the hip, and at the level of the calf to counterbalance the body and avoid compensation of other parts of the body during the test. A Velcro strap was fixed around the skull at the level of the forehead, immediately above the ears. A level goniometer (LIC rehab Vardrum, Solna, Sweden) was placed on the Velcro strap immediately above the superior tip of the left ear and was used as a gravity inclinometer in the sagittal plane. A string connected with a very light metal hook was attached to the Velcro strap at the point of the subject's eyebrows and hung 3 cm from the floor in pendular fashion. This string was connected with a visual biofeedback system comprised of a series of colored lights which indicated to the subject when the position was lost.[16, 27] (Figure 10-2)

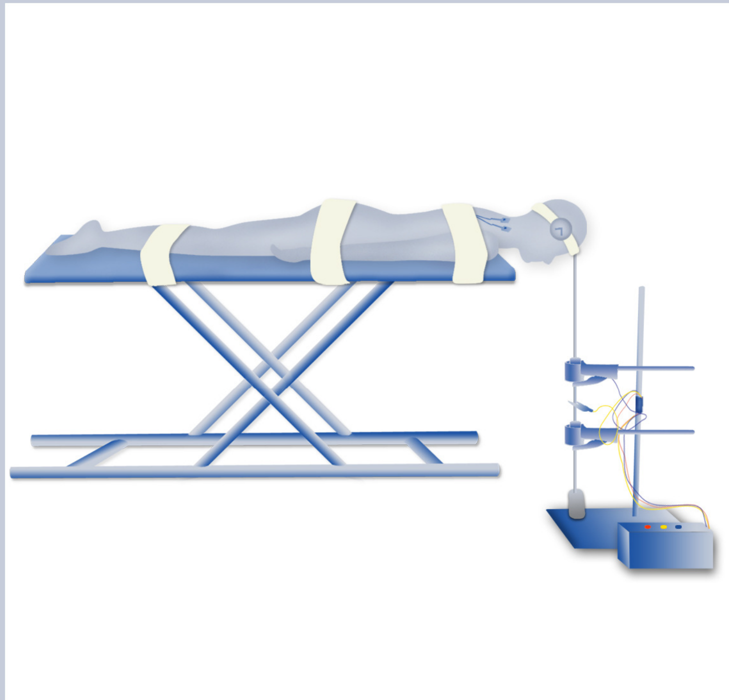


Figure 10-2. Neck Extensor Muscle Endurance Test (NEMET).

10.4.5.2 Experimental Procedure

Subjects were asked to maintain the position described above as long as possible but without supporting their heads. Subjects were reminded about the correct test position but they were not encouraged during the test. The test position was carefully monitored by an assessor (a physical therapist) and immediately corrected if the standardized test position was not maintained. Thus endurance holding time was measured with a stopwatch after removing the neck support and asking the subjects to hold the position of the head steady with the chin retracted and the cervical spine horizontal to the floor (Figure 10-2).[16, 27] Holding time of the neck extensor endurance test along with the electromyographic signals for cervical extensor muscles were recorded.

The test was discontinued if: [16]

1. The subject complained of fatigue or pain in the neck or if the subject complained of intolerable pain in another part of the body (i.e. thoracic spine, interscapular region, low back)

2. The subject could not maintain the head in the horizontal position. This was determined when the lights were "on" for longer than 5 seconds on more than 5 occasions.

3. The subject lost more than 5º of upper cervical retraction for more than 5 seconds as measured by the level goniometer located in the subjects' head (LIC rehab Vardrum, Solna, Sweden).

10.4.6 EMG DATA PROCESSING

EMG data from the cervical extensor muscles was recorded (analog raw signal), and was sampled to 1024 Hz, band-pass filtered between 20Hz-450Hz, and amplified using a gain of 1000. The samples were digitized by a 16 bit A/D converter and stored on a computer, according to the established standards for EMG acquisition and reporting.[43, 44]

During sustained contractions, metabolic and neuromuscular changes occur in the muscles. It has been documented that these changes cause a linear decrease of the median frequency overtime. The faster this decrease is, the steeper the slope of the median frequency is (higher negative value of the slope) indicating that fatigue is occurring more rapidly.[45, 46] The slope of the median frequency is known as fatigue Index. Thus, fatigability of the cervical extensor muscles was determined by analyzing the EMG activity through the measurement and analysis of the median frequency (MDF) of the EMG spectrum and the slope of the MDF of the EMG signal obtained through a Fast Fourier Transform (FFT) procedure using a computerized algorithm. To allow comparisons between subjects, the time course of each EMG variable was normalized with respect to the intersection of the regression line in the fatigue plot.[45] Thus, a fatigue index was obtained for every subject at different times and was compared between patients with TMD (i.e. mixed and myogenous TMD) and control subjects. Electromyographic signals were analyzed offline using IGOR Pro5.1 (see http://www.wavemetrics.com/index.html) by a blinded assessor.

10.5 ANALYSIS

The data on the EMG activity of all muscles was analyzed descriptively (i.e. mean, standard deviation).

A mixed model analysis using a natural cubic spline was used to evaluate the differences in normalized median frequency (i.e. fatigue index) at different times for the cervical extensor muscles while performing the neck extensor muscle endurance test between subjects with TMD and control subjects (objective 1). A one way ANOVA test was used to evaluate the differences in holding time between patients with TMD (i.e. myogenous TMD and mixed TMD) and healthy subjects. Paired comparisons using the Bonferroni procedure were administered to evaluate the differences in holding time between groups (control and patients with

TMD) (objective 2). The level of significance was set at α = 0.05. The SPSS© (SPSS Inc, Chicago), Statistical Program version 17.0 (Statistical Package for the Social Sciences) and STATA 10 were used to perform the statistical analysis. The analysis was performed blinded to group condition.

10.6 RESULTS

10.6.1 SUBJECTS

A total of 169 subjects were assessed for inclusion in this study. A total of 18 subjects were excluded. The main reasons for exclusion were: not being totally healthy (9 subjects), being older than 50 years old (2 subjects), having a neurological disease (1 subject), having cancer (1 subject), or the pain score was lower than 30 mm on the visual analogue scale (5 subjects).

One hundred and fifty one participants (151) provided data for this study. From these 151 subjects, 47 subjects were healthy, 57 subjects had myogenous temporomandibular disorders (TMD) and 47 subjects had mixed TMD.

The general demographics for each group are as follows (Table 10-1):

Table 10-1. Descriptive Statistics of Heaight, Weight, and Age for all Subjects by Group (i.e. Myogenous TMD, Mixed TMD, and Healthy).

	Group	Mean	Std. Deviation	N
Height (cm)	Healthy	165.05	6.76	47
	Myogenous TMD	164.78	5.18	57
	Mixed TMD	166.13	5.92	47
Weight (Kg)	Healthy	64.32†	12.68	47
	Myogenous TMD	64.21†	11.12	57
	Mixed TMD	71.46*	15.88	47
Age (years)	Healthy	28.26	7.46	47
	Myogenous TMD	31.11	8.70	57
	Mixed TMD	31.38	8.42	47

*** Significantly different when compared with healthy subjects at α=0.05**
† Significantly different when compared with subjects with mixed TMD at α=0.05

10.6.2 Sample Characteristics

There were no significant differences in age or height by group. However, body weight was significantly different between healthy subjects and subjects with mixed TMD (mean difference=7.14 kg [95%CI 0.53, 13.75] p=0.029) and between subjects with myogenous TMD and mixed TMD (mean difference=7.25 kg [95%CI 0.94, 13.56] p=0.018).

Subjects with TMD (i.e. mixed and myogenous) were significantly different from healthy subjects in all symptom characteristics (i.e. pain intensity, duration of complaint, Neck Disability Index Score and Jaw Disability Score). Subjects with mixed TMD were similar to subjects with myogenous TMD in most of the general characteristics such as duration of complaint (in years) and pain intensity (p>0.05). The average pain intensity on the VAS scale for patients with myogenous TMD was 45.2 mm and 49.1 mm for subjects with mixed TMD.

Regarding duration of complaint, most of the patients had a long history of pain with an average of 8.2 years of pain for subjects with mixed TMD and an average of 6.2 years for subjects with myogenous TMD.

Both groups did not present with a high level of dysfunction either in the neck or in the jaw. The maximum score for the Neck Disability Index is 50 points. Subjects with mixed TMD only had an average score on the NDI of 12.62 points and the subjects with myogenous TMD had an average of 10.88 points. Both values are considered only mild neck disability.[46, 48] Related to the Jaw Function Scale, the maximum score is 50 points and the average obtained by subjects with mixed TMD and myogenous TMD was 22.55 points and 18.84 points respectively. Thus, based on these two scales, the severity for both types of dysfunction in this sample of patients was not severe.

The JFS Score was significantly higher statistically for subjects with mixed TMD compared to myogenous TMD subjects. (Mean difference 3.7 points, p=0.003 [95%CI 0.998, 6.42]). Neck Disability Scores were not significantly different statistically between subjects with mixed TMD when compared with myogneous TMD, however, subjects with mixed TMD presented with a higher disability score than the subjects with myogenous TMD (mean difference 1.74 points).

Table 10–2. Clinical Characteristics for all Subjects by Group (i.e. Myogenous TMD, Mixed TMD, and Healthy).

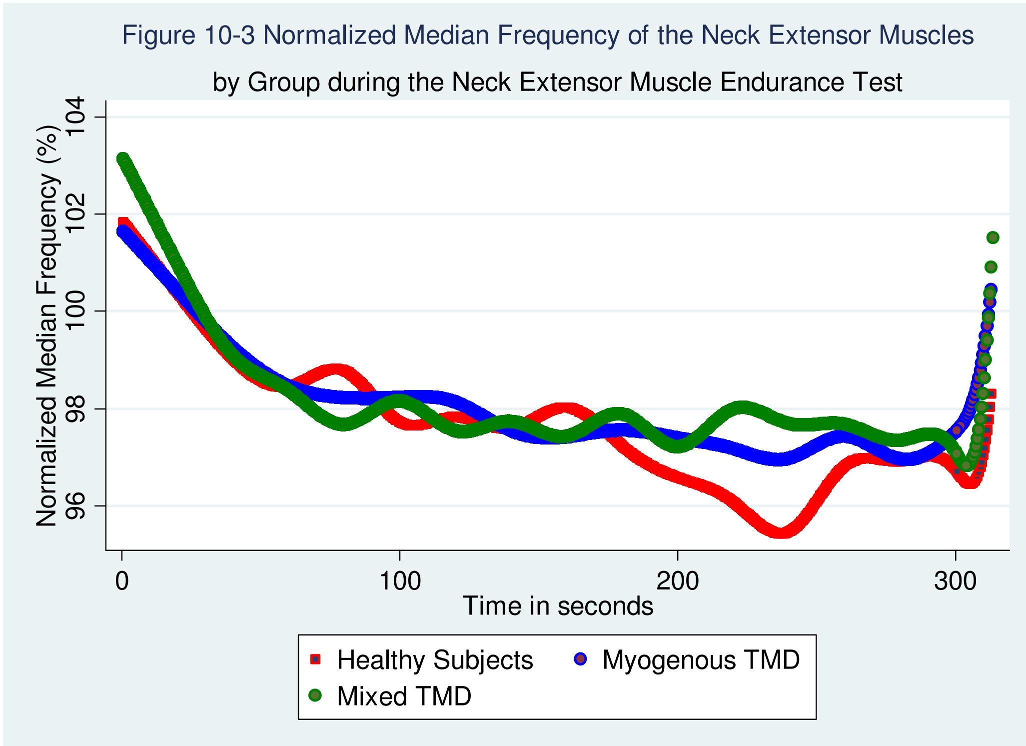
Variable	Group	Mean	SD	N
Duration of complaint (years)	**Healthy**	**0.00**	**0.00**	47
	Myogenous TMD	**6.22***	**6.36**	57
	Mixed TMD	**8.22***	**6.50**	47
Pain Intensity (VAS) (0-100 mm)	**Healthy**	**0.00**	**0.00**	47
	Myogenous TMD	**45.24***	**18.26**	57
	Mixed TMD	**49.06***	**16.09**	47
Jaw Function Scale (JFS) (10-50 points)	**Healthy**	**10.13**	**0.40**	47
	Myogenous TMD	**18.84*†**	**6.62**	57
	Mixed TMD	**22.55***	**7.11**	47
Neck Disability Index (NDI) (0-50 points)	**Healthy**	**1.62**	**1.54**	47
	Myogenous TMD	**10.88***	**6.0**	57
	Mixed TMD	**12.62***	**6.91**	**47**

*** Significantly different when compared with healthy subjects at α=0.05**
† Significantly different when compared with subjects with mixed TMD at α=0.05

10.6.3 ELECTROMYOGRAPHIC ANALYSIS OF THE ENDURANCE OF THE CERVICAL EXTENSOR MUSCLES BETWEEN PATIENTS WITH MYOGENOUS TMD, MIXED TMD, AND HEALTHY SUBJECTS

A mixed model analysis (using a natural cubic spline) determined that significant differences in normalized median frequency (i.e. EMG fatigue index) at different times for both cervical extensor muscles (right and left) while performing the neck extensor muscle endurance test between subjects with TMD (i.e. myogenous and mixed TMD) and control subjects (Wald chi2(53) = 2795.30; Prob > chi2 = 0.0001) after adjusting for age, height and weight were found. The graphs showing the median frequency at different times by groups demonstrated that groups behaved differently in the way the normalized median frequency dropped at different times (Figure 10-3). There were statistical significant differences (although modest) in the slopes of the normalized median frequency between subjects with TMD and healthy subjects at 10, 30, 40, 50, 60, 70, 80, 90, and 100 seconds. Subjects with mixed TMD had a steeper drop of the normalized median frequency than healthy subjects at 10, 30, 50, 70, and 90 seconds (β: -0.04 p= 0.003, 95%CI -0.06, -0.01; β:-19.41, p=0.032, 95%CI -37.19, -1.64; β: -37.80, p= 0.021, 95%CI -69.8, -5.78; β: -71.40, p=0.000, 95%CI -105.67, 37.14; β: -61.63, p= 0.001, 95%CI -98.88, -24.37298; β:-60.40, p=0.006 95%CI -103.18,-17.61 respectively) indicating a higher fatigability of the neck extensor muscles when performing the NEMET than healthy subjects at these times. However, patients with mixed TMD presented with a significantly less steep normalized median frequency slope than healthy subjects at 40, 60, 80, and 100 seconds (β: 45.98, p=0.002, 95%CI 16.95, 75.02; β:74.42 p=0.000, 95%CI 38.21, 110.63; β:57.86, p=0.004, 95%CI 18.90, 96.81; β: 54.82, p=0.026, 95%CI 6013, 103.04 respectively)

Subjects with myogenous TMD presented with a significantly steeper drop of the normalized median frequency than healthy subjects at 50 seconds only. In addition differences between subjects with mixed TMD and myogenous TMD were observed at 80, 90, 100, 110, and 120 seconds. These results indicated a different pattern of response of each group to sustained contractions.



10.6.4 ENDURANCE OF THE CERVICAL EXTENSOR MUSCLES EVALUATED THROUGH THE HOLDING TIME WHILE PERFORMING THE NECK EXTENSOR MUSCLE ENDURANCE TEST AMONG GROUPS

A one way ANOVA test determined that there were statistically significant differences in holding time among the groups (Table 10-3).

Table 10–3. Test of Between Groups while Performing the Neck Extensor Muscle Endurance Test.

Dependent Variable: Holding time during the Neck extensor muscle endurance test (sec)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.413E6	2	706418.520	4.229	0.016
Intercept	4.161E7	1	4.161E7	249.136	0.000
Group	1412837.041	2	706418.520	4.229	0.016*
Error	2.472E7	148	167032.493		
Total	6.734E7	151			
Corrected Total	2.613E7	150			

***Significant at α=0.05**

The estimates for holding time by group are displayed in Table 10-4.

Table 10–4. Estimates of Holding Time while Performing the Neck Extensor Muscle Endurance Test by Group.

Dependent Variable: Neck Extensor Muscle Endurance Test (seconds)

Group	Mean (seconds)	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Healthy	666.255	59.614	548.450	784.061
Myogenous TMD	455.456	54.133	348.482	562.430
Mixed TMD	459.702	59.614	341.897	577.508

Paired comparisons using a Bonferroni procedure demonstrated that holding time was significantly reduced in both subjects with myogenous TMD and mixed TMD when compared with healthy subjects (Table 10-5, Figure 10-4). No differences in holding time were found between subjects with myogenous TMD and mixed TMD. The most common complaint at termination of the test was pain in the lower cervical spine as well as pain in the upper and middle dorsal spine (interscapular region). Most subjects tended to lose the ability to hold the head in the testing position in a vertical way (the head tended to go down vertically) and then subjects lost the ability to hold the chin retracted.

Table 10–5. Pair Wise Comparisons for Neck Extensor Muscle Endurance Test (sec) by Group.

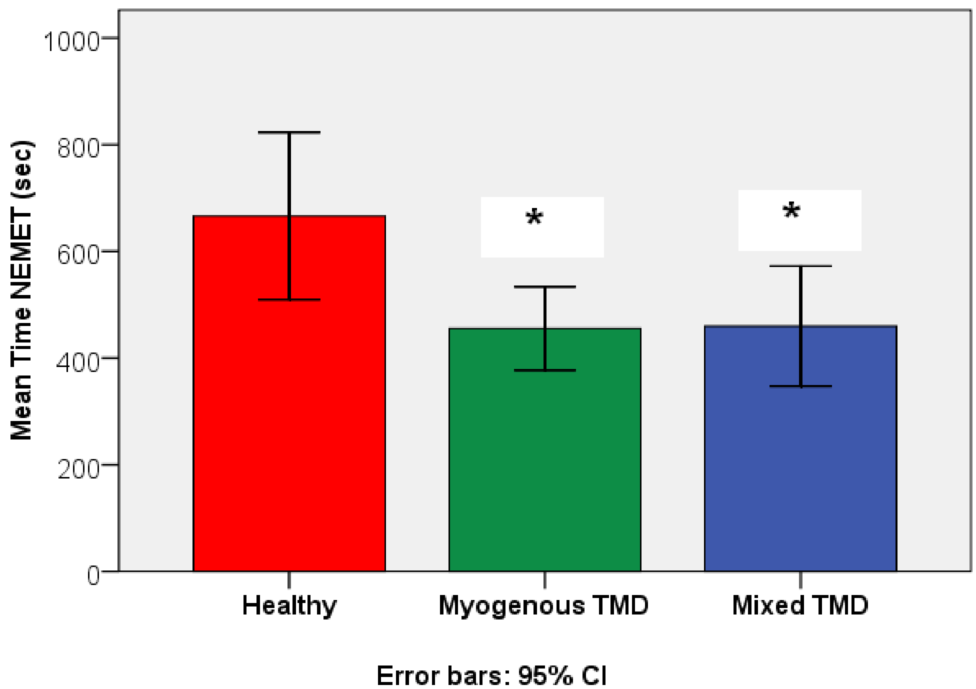
Dependent Variable: Time NEMET in sec

Group	Group	Mean Difference between Groups	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Healthy	Myogenous TMD	210.799*	80.525	0.029	15.808	405.790
	Mixed TMD	206.553*	84.308	0.046	2.403	410.704
Myogenous TMD	Mixed TMD	-4.246	80.525	1.000	-199.237	190.745

[a] Based on estimated marginal means
*. The mean difference is significant at the 0.05 level.

Age, height, and weight were not significantly associated with holding time (p>0.05), so, they were not included in the model.

Figure 10-4. Endurance of the Neck Extensor Muscles Measured through Holding Time During the Neck Extensor Endurance Test in Subjects with Myogenous TMD, Mixed TMD and Healthy Subjects



* **Significantly different when compared with healthy subjects at α=0.05**

10.6.5 Association between Holding Time and Neck Disability, Jaw Disability, Pain Intensity, and Time of Complaint.

Negative significant correlations (although weak) were found between holding time while performing the NEMET and clinical variables such as neck disability, jaw disability, and pain intensity (Table 10-6). These correlations indicate that the more pain intensity in the jaw, more disability in the jaw and neck were related to a less holding time in this sample.

Table 10–6. Association between Holding Time with Neck Disability, Jaw Disability, Pain Intensity, and Time of Complaint.

		time of complaint	Jaw Function Scale	Neck Disability Index	Pain Intensity
Time NEMET in sec	Correlation Coefficient	-0.116	-0.252**	-0.374**	-0.309**
	Sig. (2-tailed)	0.155	0.002	0.000	0.000
	N	151	151	151	151

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

10.7 DISCUSSION

The main results of this study were that subjects with TMD had significantly lower holding time when performing the neck extensor muscle endurance test compared with healthy subjects. In addition, subjects with TMD (i.e. myogenous and mixed TMD) presented with a different pattern of normalized median frequency drop, than healthy subjects as evaluated by electromyography. Patients with mixed TMD presented with steeper negative slopes (although modest) at several times during the NEMET than healthy subjects. **These results support the 1st and 2nd hypotheses of this study.** This could indicate that cervical extensor muscles of subjects with mixed TMD could have a different pattern of responding to sustained contractions presenting with more fatigue than healthy subjects. These results are also corroborated by less holding time found in this group of patients when compared with healthy subjects. In addition, subjects with myogenous TMD also presented with a reduced holding time evaluated through the NEMET than healthy subjects. These results have important clinical applications for physical therapists working in the TMD field. They highlight that subjects with mixed TMD who generally have a more intense jaw pain, as well as have more disability, have less endurance capacity of the neck extensor muscles than healthy controls. In addition, they pointed out a path for future treatment in these patients.

The study of neck extensor muscles endurance has not been previously investigated in subjects with TMD. Thus, this study contributes to the evidence of the relationship between neck extensor endurance and the presence of TMD.

The neck extensor muscle endurance test has been investigated in different populations with cervical spine involvement such as mechanical neck pain,[16] subclinical neck pain,[14, 15] chronic postural neck pain,[29]neck discomfort [25] and subjects with cervical disk disease (who had anterior cervical decompression and fusion).[26] All of the above studies agreed that neck extensor muscle endurance was reduced when compared with healthy subjects and the results of this present study agreed with these studies. This indicates that patients with neck involvement presented with lower endurance capacity than healthy subjects. These results have clinical applications since physical therapists, who work in the TMD area, can search for the presence of altered endurance in these patients and they can plan a more effective and focused treatment plan looking at improving the endurance capacity of the neck extensor muscles through exercises. The improvement in the endurance of the neck extensor muscles could lead to an improved function of the cervical spine and as a result symptomatology at that level could be lessened.

The results of this study also highlight that electromyographic differences were observed in the pattern of response to sustained contractions by different groups of subjects (i.e. myogenous TMD, Mixed TMD, and healthy subjects). Subjects with mixed TMD presented with significantly differences (although mild) in normalized mean frequency drop, as evaluated by EMG, when compared to healthy subjects and subjects with myogenous TMD. The pattern of normalized mean frequency drop was more accentuated in subjects with mixed TMD at several times when compared with healthy subjects. This could indicate that subjects with mixed TMD had a tendency to demonstrate a higher fatigability of the cervical extensor muscles when compared with healthy individuals. This could also indicate that subjects with mixed TMD have a different strategy for adapting to sustained contractions than healthy subjects and subjects with myogenous TMD do. Patients with myogenous TMD only presented with a steeper normalized median frequency drop at one time (50 seconds) during the test compared to healthy individuals. Thus, no clear differences in the EMG pattern of response of the cervical extensor muscles to sustained contractions between subjects with myogenous TMD and healthy subjects were found. However, subjects with myogenous TMD presented with a reduced holding time in the NEMET when compared with healthy subjects. This could indicate that even though subjects with myogenous TMD presented with less endurance of the neck extensor endurance muscles, this was not evident in the electromyographic analysis. One explanation for this could be that the modest or no changes observed in the EMG in subjects with mixed TMD and myogenous TMD when compared with healthy subjects was due to the nature of the present study set up. The NEMET is a low-force test characterized by a low level of contraction during the whole procedure (i.e. <20%MVC). According to Peolsson et al.,[25], the level of activity of the neck extensor muscles during the NEMET is about 5-6% of the MVC. It has been acknowledged that the electromyographic evaluation of the fatigue under low-force protocols is complex and offers contradictory results.[47] Most of the changes described in the EMG spectral variables such as mean and median frequency of the EMG spectrum have been reported in moderate and high force contraction levels. Farina et al., [48] found that surface EMG presented with some limitations for demonstrating EMG changes during sustained contractions of low-force. This also has been acknowledged by Roman-Liu and Konarska in trapezius and digitorum superficialis muscles [49] and Yassierli and Nussbaum.[47] Farina et al.[48] found that even though changes in conduction velocity of the motor units (MUs) significantly decreased over time, the EMG power spectral frequency of the surface EMG did not show a clear pattern of fatigue. In the present study, both groups of subjects with TMD pain presented with a reduced holding time, evidencing a poorer endurance capacity of the cervical extensor muscles than healthy subjects. However these changes were not captured or were only slightly captured by the EMG spectrum variables. The possible explanation of this phenomenon could be due to the fact that during a sustained contraction there is recruitment and de-recruitment of MUs. If the number of MUs during the contraction is maintained stable, changes in conduction velocity (CV) could be reflected in the EMG spectral variables. However, because of recruitment and de-recruitment of MUs, the decrease in CV could be masked by newly recruited MUs. This factor is particularly important for low-force level contractions since changes in CV are small compared to recruitment of MUs. The opposite occurs in moderate and high level contractions when recruitment is almost insignificant and changes in CV are large.

In addition to the previous explanation, it should be acknowledged that surface EMG variables such as mean and median frequency can be influenced by several factors such as interelectrode distance, the thickness of the subcutaneous layer, cross talk among nearby muscles, and location of the electrodes over the muscle among others.[46] The registered signal from the cervical extensor muscles reflects the activity of many cervical extensor muscles underlying the electrode. This can contribute to determine a less clear pattern of fatigue due to the contribution of neighbouring muscles to maintain the desired level of contraction during a sustained activity. In addition, Farina et al., [48] suggested that at low contraction levels, the changes of the EMG variables to be detected are small in comparison with the signal noise ratio. Thus, small changes in the EMG spectrum are more difficult to detect at lower level contractions than at higher levels.

In the present study, a Fast Fourier Transform (FFT) procedure was used to evaluate the EMG variables that indicated fatigue. Due to the instability of the signal due to an unstable firing rate of MUs at low contraction levels, wavelet analysis has been suggested to analyze the EMG frequency spectrum of these types of contractions due to the non-stationary nature of these EMG signals.[49] Future studies should look into this issue when determining fatigue during low-force contractions.

Studies investigating fatigue of the extensor cervical muscles through electromyographic assessment in patients with TMD while performing the NEMET are lacking. This fact makes it difficult to compare the results obtained by the present study with others. Also the electromyographic assessment of the neck extensor muscles has been scarce in other populations with cervical spine involvement. Few articles [50, 51] were found that investigated the endurance of the cervical extensor muscles in patients with chronic non-traumatic neck pain. However, these reports evaluated the endurance of the neck extensor muscles in a sitting position using a special set up. Thus their results are not totally comparable with the results of the present study.

The clinical evaluation of neck extensor muscle endurance, as mentioned previously, has been studied in many populations with neck involvement. [14-16, 24-28] The neck extensor muscle endurance test (NEMET) [27, 28] has been used to determine endurance of the neck extensor muscles endurance because of its good reliability, simplicity, and its potential use in clinical practice.[25, 29] Many modifications of this test have been performed. Some authors have performed this test with the use of standardized weights over the subjects' heads [24-29] while others have done it without loads. [14-16] Thus, a great deal of variation in the results regarding holding times have been observed (holding times between 1.5 minutes and 8.8 minutes for subjects with neck pain; and between 6 minutes and 10 minutes for healthy subjects). Some studies have used no weight over the head when performing the NEMET in order to use a more functional and comfortable way to evaluate endurance of the neck extensor muscles. However, as mentioned above, electromyographic evaluation of fatigue using such low-load conditions can have some limitations. In addition, the sitting position has also been used to determine fatigue in the neck extensor muscles.[50, 51] According to a recent report,[52] test position significantly influences the EMG variables of fatigue for the cervical extensor muscles. Splenius capitis presented higher fatigue in lying than in sitting position at high levels of muscular contraction. Thus, these results pointed out the necessity to carefully standardize test position when studying endurance of the neck extensor cervical muscles. Furthermore, the use of known levels of maximal voluntary contraction when performing the NEMET through the use of a load cell and a visual feedback could add more standardization to the test and could help establishing more accurate measurements of fatigue at different levels of MVC and avoiding the termination of the test due to boredom due to long hold times.[24]

In this study, neither holding time nor normalized median frequency during the NEMET were associated with age, height and weight of the individuals. These results are in line with those found by Peolsson et al.[24] and could indicate that structural factors of the individual have no implications in the endurance capacity of the neck extensor muscles. However, Lee et al.,[16] found that size of the head and neck could have some influence in predicting neck extensor muscle endurance. However, these factors were not considered in this present study. This study also found weak negative significant correlations between holding time while performing the NEMET and clinical variables such as neck disability, jaw disability, pain intensity, and time of complaint. Thus, the third hypothesis of this study was not supported. These results are in line with those of Peolsson et al.,[26] who found moderate correlations between neck extensor endurance test, pain intensity and neck disability. These results could indicate that subjects with more pain, more years of complaint as well as having more neck and jaw disability presented with less holding time and consequently have more fatigability of the neck extensor muscles.

Muscle endurance has been recognized as an important factor for proper function of spinal segments that allows spinal muscles to maintain the stability of the spinal system.[53] The human body requires muscles to be able to tolerate loads and to be active for long periods of time to maintain proper function. Neck muscles (i.e. flexors and extensors) have to stabilize the head and neck to maintain posture and resist perturbations. All of these activities make neck muscles to be considered as complex structures with multiple tasks for maintaining the normal functioning of the cervical spinal system. Since cervical muscles' role is to maintain stability while allowing mobility of the neck, endurance capacity has been considered an important element for assessing and treating in patients with cervical involvement.[14-16, 26] For example, Falla et al., found that training of muscle endurance in the cervical spine helped to reduce neck pain intensity as well as decrease neck disability.[22] Peolsson et al.,[26] also obtained similar results in a population of patients with neck pain and subjects with cervical disk disease after anterior cervical decompression and fusion. Thus, these results point out that training protocols addressing endurance of the neck extensor muscles **could** have a positive impact on pain and function in subjects with neck involvement. Thus, furher research is needed to determine whether exercise programs would be effective in patients with TMD.

10.8 CONCLUSIONS

There were significant differences statistically in holding time and normalized median frequency drop between subjects with TMD when compared with healthy subjects. Subjects with TMD presented with a reduced endurance of the cervical extensor muscles. These results highlight the fact that alterations of endurance capacity of the extensor cervical muscles could be implicated in the neck-shoulder disturbances presented in patients with TMD. These results can help guide clinicians in the assessment of fatigability of the neck extensor muscles in subjects with TMD and perhaps would help in prescribing more focused interventions addressing this impairment for individuals with TMD.

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11 CHAPTER 11

GENERAL DISCUSSION AND CONCLUSIONS

11.1 INTRODUCTION

Temporomandibular Disorders (TMD) have been considered a major public health problem as they are the main source of chronic orofacial pain. TMD are the most prevalent category of nondental chronic pain conditions in the orofacial region. TMD interfere with daily activities and can significantly impact quality of life, diminishing patients' capacity for work and/or ability to interact with their social environment.[1] TMD can also cause nutritional deficiency due to the discomfort related with eating. In addition, TMD have been considered to have a great economic impact due to TMD direct care.[2] TMD chronic pain has been shown to have similar individual impact and burden as back pain and severe headache. TMD have been recognized as complex disorders, thus their treatment involves a multidisciplinary team including dentists, physicians, physical therapists, psychologists, speech language pathologists among other health professionals. Many different therapies have been used to treat this condition. Medications, occlusal splint therapy, physical therapy, psychotherapy, acupuncture, and behavioral therapy interventions among others have been used to decrease patients' symptomatology. However, research in this area (i.e. TMD and orofacial pain) is in its infancy and more rigorous research studies are needed in order to determine the best interventions for TMD. Until now, research evidence has supported the use of conservative and reversible treatments (e.g. physical therapy, dental appliances, behavioral therapy) to treat the majority of patients with TMD.

A paradigm shift has occurred, in the way to approach TMD regarding its assessment, diagnosis as well as its treatment. According to Laskin, [3] TMD in the past were treated based on opinions of strong personalities and anecdotal success stories. With the advance of research and the introduction of evidence based medicine at the beginning of the eighties, all health areas, including dentistry and physical therapy needed to demonstrate that their interventions were based on scientific grounds and not merely anecdotal experiences. This motivated clinicians and researchers to test their theories used for determining diagnosis, assessment, development of conditions, as well as those that were related to interventions. The area of TMD did not escape this advancement and thus many researchers and clinicians in this area have promoted the creation of new higher quality research in different areas related to TMD and orofacial pain such as basic sciences (e.g. biology, neurophysiology, and physiology) and clinical research (i.e. diagnosis, treatment and prognosis) in order to meet the demands of this new era. One example in this context has been the creation and the use of a recognized common vocabulary to assess and diagnose TMD conditions. The creation of the RDC/TMD has been recognized as the first step in contributing to a better understanding of the major conditions included under the umbrella term of TMD. However, according to some researchers [3, 4] even though this has been recognized as a model system for the standardization of the investigation of diagnosis and classification of any TMD condition, a new revision of its definitions and procedures needs to be performed in order to meet the needs of clinicians. Steenks and de Wijer, [5] for example, felt that RDC/TMD criteria were unbalance in the number of muscular and articular palpation sites which could lead to an overrepresentation of muscular conditions at the expenses of articular pain conditions when determining TMD diagnoses. In addition, the use of some unreliable muscle palpation sites such as intraoral muscles and submandibular muscles and the arbitrary cut offs of 3 painful palpation sites could increase the probability of false positives results for myogenous muscular pain as well. Furthermore the algorithm to determine articular compromise from the RDC/TMD is only based in ongoing pain. Compression, retrusion and joint play (i.e. traction test) are not included in the examination protocol used by the RDC/TMD. All of these shortcomings were addressed in the current study. Although the present study used the guidelines established by the RDC/TMD, some additional assessment and variation of measurements were performed. Only 12 muscular palpation sites were considered because they were the only ones that were easily accessible to allow an objective palpation procedure as acknowledged by Fricton [6] and Steenks and De Wijer.[5] Also, manual testing of the joint through the use of the compression and retrusion tests was added in order to determine whether there was articular compromise of the TMJ as suggested by these authors as well.

Visscher et al.,[7] also found in a recent study that the use of dynamic/static tests (i.e. when the patient performed mandibular movements while the evaluator applied a manual overpressure) had better diagnostic accuracy showing higher positives likelihood ratios (4.06 for the dynamic/static tests vs.1.60 for the RDC/TMD) for confirmation of a suspicion of TMD pain when compared to the RDC/TMD. Another group of researchers also tested a new clinical algorithm for diagnosing TMD based on clinical key findings obtained from the patient's history.[8] They found that this method offered a more intuitive and convenient approach for dentists and clinicians working in this area to readily and accurately diagnose TMD due to its simplicity, and thus this algorithm could be easily accepted and used by clinicians in general practice. With all this new evidence, a group of researchers in TMD have undertaken a modification and improvement of the RDC/TMD and it is expected that in the near future a new revised version of the RDC/TMD will be promoted.[4, 9]

From the physical therapy point of view, TMD has been an area of concern for many years since physical therapy is commonly used to treat the physical impairments presented by patients with TMD and orofacial pain. Physical therapy treatment for TMD addresses many different areas. Physical therapy is used to relieve pain in the temporomandibular joint (TMJ) and masticatory muscles, as well as to relieve pain in surroundings areas (i.e. cervical joints and cervical muscles). In addition, physical therapy has been used to improve TMJ and cervical range of motion as well as improve function of the masticatory and craniocervical systems through physical modalities, exercises and manual techniques. Furthermore, since TMD has commonly been associated with other conditions affecting the head and neck region such as headache, neck pain, and neck muscular dysfunction, physical therapy treatment has focused on improving craniocervical muscular equilibrium. Physical therapy clinicians perform exercises to maintain a healthy cervical system (i.e. maintain the balance between the various muscles to maintain equilibrium of the craniomandibular system) in order to avoid overloading of the cervical system and subsequently avoiding cervical symptoms such as spasm of the cervical muscles, cervical pain, or referred pain from cervical spine to the masticatory system that are present in TMD patients. In addition, clinical studies have found that physical therapy intervention including neck exercises to correct head and neck posture could be effective in relieving muscle pain and improving jaw function in patients with TMD.[10] Therefore, the physical therapy area is closely involved with the treatment of TMD and consequently has been involved in looking at better methods to diagnose or recognize physical impairment in patients suffering from this condition to provide more effective treatment options to these groups of patients.

11.2 OBJECTIVES AND IMPETUS FOR THIS RESEARCH

As described above, important part of the physical therapy treatment for TMD includes the treatment of the cervical spine and its biomechanical equilibrium. This approach has been used by therapists for many years based on the neurophysiological, biomechanical, and functional connections between the cervical spine and orofacial region as well as the clinical association between TMD and CSD.[11]

The association between the cervical spine and craniofacial area has been studied in many ways and from different perspectives, however, a more specific approach looking at specific structures such as cervical muscles and their significance in the development and perpetuation of TMD has not been elucidated. It was evident to the researcher that the evidence supporting physical therapy treatments for TMD needed to be scrutinized in order to determine which theories linking CSD and TMD had scientific merit and also to identify which cervical structures were linked to TMD. Since physical therapists work mainly on posture retraining and the muscular system through the use of exercises, it was clear that research focusing more specifically on the cervical muscular system and its impairments and their association with TMD could clarify the role of the cervical muscles in the symptomatology of patients with TMD. No studies were found that studied the functioning of the cervical muscles through the evaluation of the strength, performance (evaluated through the craniocervical flexion test [CCFT]), or endurance capacities of both flexor and extensor cervical muscles in patients with TMD. Without knowledge of these impairments, clinicians have been treating the cervical spine of patients with TMD in a blinded way. This means that clinicians have commonly planned exercises for the cervical spine based on their intuition, their own experience, but without clear scientific evidence. Therefore, treatment for patients with TMD was considered more trial and error and thus more time and resources were spent in order to determine which exercises were more appropriate for this condition. Therefore, the overall aim of this research project was to determine the cervical involvement in TMD, specifically looking at alterations in head and cervical posture, maximal cervical muscle strength, endurance of the cervical muscles, and performance of the cervical flexor muscles (as evaluated by the CCFT) as well as the presence of neck disability in patients with TMD. The results of this project, therefore, will provide an advancement in the identification of cervical muscle dysfunction in patients with TMD and will greatly help to guide clinicians in prescribing effective physical therapy interventions for individuals with TMD. This research will help clinicians evaluate patients with TMD and their craniocervical system. Also, clinicians can focus on evaluating the cervical muscular system more specifically, using clinical tests to determine the functioning of the cervical muscles such as the CCFT, the cervical flexor muscular endurance test and the NEMET test. Furthermore, they could focus on targetting these impairments and thus using more effectively treatment resources. Identifying sources of dysfunction in patients with TMD will make effective treament options more readily available and will ultimately contribute to reducing the cost of overall health and personal care as well as improve the quality of life of individuals with TMD. This research is the first step in the advancement of the physical therapy area for evaluating and treating patients with TMD. It identifies potential areas for further research based on physical therapy (PT) evidence-based-practice and highlights the importance of using clinical research to make physical therapy interventions based on evidence and not merely in anecdotal experiences.

11.3 RESEARCH QUESTIONS

The following research questions guided this project:

1. What was the evidence and its quality related to the association between cervical spine, stomatognathic system, and craniofacial pain?

2. What was the evidence and its quality related to the association between head and cervical posture and TMD?

3. Was there any relationship between neck disability and jaw disability?

4. What kind of cervical involvement was present in patients with TMD?

5. Did subjects with mixed and myogenous TMD present with altered head and cervical posture when compared with healthy subjects?

6. Did subjects with myogenous and mixed TMD have reduced maximum cervical flexor muscle strength when compared with normal subjects?

7. Did subjects with myogenous and mixed TMD have reduced cervical flexor muscle endurance when compared with normal subjects?

8. Did subjects with myogenous and mixed TMD have altered cervical flexor muscle performance (as evaluated by the CCFT) when compared with normal subjects?

9. Did subjects with myogenous and mixed TMD have reduced cervical extensor muscle endurance while performing the NEMET when compared with normal subjects?

11.4 RESEARCH HYPOTHESES

The following research hypotheses were investigated in this project:

1. There will be a strong association between jaw disability and neck disability.

2. Patients with TMD will have altered cervical and head posture, measured through angles commonly used in clinical research settings, when compared with healthy individuals.

3. Patients with TMD (i.e. myogenous and mixed) will have a decreased maximal cervical flexor strength when compared to healthy subjects.

4. Patients with TMD (i.e. myogenous and mixed TMD) will have a reduced endurance (measured through the holding time [in seconds]) of the cervical flexor muscles at different levels of muscular contraction (i.e. 25%, 50%, and 75% maximum voluntary contraction) when compared with healthy subjects.

5. Patients with TMD (i.e. myogenous and mixed TMD) will have increased cervical muscular activity of the superficial muscles (i.e. sternocleidomastoid and anterior scalenes) when executing the craniocervical flexion test compared with normal subjects.

6. Patients with myogenous TMD (i.e. myogenous and mixed TMD) will have greater muscular fatigability in the cervical extensors muscles (i.e.

midcervical paraspinal muscles [trapezius, capitis group, and cervicis groups]) when performing a neck extensor endurance test when compared to normal control subjects.

11.5 DESIGN AND METHODS

This project was comprised of 8 studies. The initial two studies were a critical review and a systematic review of the literature. The remaining six studies were cross sectional in design. They investigated the relationship between neck disability and jaw disability, the physical functioning of the cervical spine through the evaluation of the head and neck posture, maximal cervical flexor muscle strength, and the endurance of the cervical flexor and extensor muscles in patients with TMD when compared with healthy subjects.

Because of the introduction of evidence based practice and the necessity of determining the quality of the evidence in this area, the first study of this project was conducted to evaluate the quality of the available evidence looking at the relationship between cervical region and craniofacial pain. This study provided the basis of the following studies performed in this project. It was realized that most of this evidence came from studies with low levels of evidence (level 3, 4 and 5, according to Sackett), and lacking of scientific rigour. However, the available research pointed out a tendency to link cervical spine and supporting structures and craniofacial pain. Following this critical review, it became evident that more rigorous studies (i.e. with greater sample sizes, using a clear diagnosis, and blinded assessment) were necessary in order to support the clinical findings found in these studies. Furthermore, another systematic review conducted as part of this project focused in the association between head and cervical posture and TMD found inconclusive results of this association due to a lack of high quality research. Most of the analyzed studies in this systematic review lacked a clear clinical diagnosis of TMD, were low powered (i.e. using small sample sizes), had inappropriate statistical analyses which impaired the accuracy of the results, did not report the reliability of the measurements and did not blind the assessor. The systematic review also identified that there was insufficient research looking at the association between head/cervical posture in subjects with myogenous TMD. All of these shortcomings were addressed by this project. In addition, another systematic review conducted by the researcher [10], although not included in the written report of this project, helped with the information regarding the necessity of demonstrating a stronger support for the physical therapy interventions. The results of this systematic review investigating physical therapy interventions for TMD[10] found that exercises used to improve posture decreased the symptoms in patients with TMD. However, the exercises used to treat posture in patients with TMD lacked a clear exercise prescription (i.e. type of exercise, dosage, frequency) as well as a clear underlying mechanism of why these exercises, directed toward to the neck, improved TMD symptoms. Based on the information provided by these reviews, the rest of the studies of this project were designed to answer the research questions outlined above.

The first of these studies explored the association between neck and jaw disability using validated and recognized tools. According to previous studies, the association between jaw pain and neck pain was only established through the presence of signs and symptoms, however, no one study was found that investigated whether jaw disability and the level of chronic disability due to TMD were associated with neck disability. Thus, this study was designed in order to answer this research question.

The rest of the studies were a series of cross sectional studies which investigated cervical musculoskeletal involvement in patients with TMD. These studies were performed with the aim of determining which cervical musculoskeletal impairments were present in subjects with TMD. Information regarding these cervical physical impairments would add to the scarcity of knowledge in this area and would identify sources of dysfunction in patients with TMD making effective treament options more readily implemented by physical therapy clinicians.

In these studies, subjects with TMD (i.e. myogenous and mixed TMD) were compared with healthy subjects for the following variables: head and neck posture, maximal cervical muscle strength, cervical flexor and extensor muscles endurance, and cervical flexor muscle performance (as evaluated by the CCFT).

Healthy subjects were recruited from students and staff at the University of Alberta. Subjects with TMD were recruited from the TMD/Orofacial Pain Clinic at the School of Dentistry, Faculty of Medicine and Dentistry, University of Alberta. The recruitment time lasted over two years.

All subjects (i.e. healthy and subjects with TMD) were evaluated by an experienced physical therapist in order to determine inclusion and exclusion criteria for this study. In addition important clinical information was collected from the participants (e.g. onset, duration of symptoms, treatments received). All subjects underwent a series of physical tests and electromyographic assessment using objective evaluation procedures and tools to determine cervical musculoskeletal alterations in patients with TMD when compared with healthy subjects. For a summary of the studies, see Table 11-1

The present project was conducted with the objective of overcoming some of the limitations found in the available literature. These studies were designed to minimize bias regarding data collection and analytical methods. The data collection procedure followed the same protocol for each subject. An adequate sample size for all groups of subjects, a clear clinical diagnosis to determine subjects' symptomatology, and blinding of the individual doing the measurements and statistical analysis were used in this project. Thus, the studies provided a stronger methodology than previous studies investigating the association between CSD and TMD.

11.6 MAIN RESULTS

The main results of this research were as follows: (for details see Table 11-1)

11.6.1 RELATIONSHIP BETWEEN CRANIOFACIAL PAIN AND CERVICAL SPINE AND RELATIONSHIP BETWEEN HEAD AND NECK POSTURE AND TMD

The critical review and systematic review performed as preliminary work for this project found that most of the analyzed studies investigating the association between neck and craniofacial pain and those studying the association between head and neck posture and TMD were of poor quality and thus no conclusive results were found. These studies highlighted a need for better designed studies investigating the relationship between neck and craniofacial pain and temporomandibular disorders and investigating the association between TMD and head and cervical posture.

11.6.2 RELATIONSHIP BETWEEN JAW DISABILITY AND NECK DISABILITY

A strong association between neck disability and jaw disability in the studied population was found. These results support the first hypothesis of this study (as stated in chapter 11). The effect size of the association (ES: 0.8) between JFS and NDI was high, indicating a relevant finding for the clinical practice. In addition, it was found that a person who has a Chronic Pain Grade Disability due to TMD grade IV increased 19.32 points on the Neck Disability Index when compared with a person without TMD disability. These results support the clinical findings regarding the relationship between CSD and TMD.[12, 13] Subjects having greater disability in the jaw were more likely to have greater disability of the neck and vice versa, although, according to the nature of this study, a cause-effect relationship could not be established. These results indicate that assessment and physical therapy treatment need to focus on both areas since the improvement of one could have an influence in the other.

11.6.3 HEAD AND CERVICAL POSTURE IN SUBJECTS WITH TMD WHEN COMPARED WITH HEALTHY SUBJECTS

Craniocervical posture (measured using the eye-tragus-horizontal angle) was statistically different between patients with myogenous TMD when compared to healthy subjects. **These results partially support the second hypothesis of this study** (as stated in chapter 11)**.** This could indicate a more extended position of the head (i.e. craniocervical region) in subjects with myogenous TMD when compared with healthy subjects. However, the difference between the two groups was small (3.3º) and these results were considered to have no clinical significance since it is very unlikely that such a small difference, as the one found in this study, would be used as a criterion for determining progression or change in posture by a clinician. Postural variables (i.e. tragus-C7-horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder) were neither associated with the level of jaw disability nor with the level of neck disability measured through the JFS and NDI respectively.

11.6.4 MAXIMAL CERVICAL FLEXOR MUSCLE STRENGTH IN PATIENTS WITH TMD AND HEALTHY SUBJECTS

Maximal cervical flexor muscle strength was not found to be different statistically or clinically between patients with TMD and healthy subjects. **These results do not support the third hypothesis of this study** (as stated in chapter 11)**.** Average differences in maximal cervical flexor muscle strength between healthy and subjects with TMD ranged between 3.73 and 4.45 Newtons. In addition, the effect sizes reached by these values were estimated to be small (ES: 0.25-0.30) indicating that the differences found among groups are not clinically relevant. Thus, maximal cervical flexor muscle strength is not reduced in subjects with TMD in this population when compared with healthy subjects. However, it is unknown if other muscular groups such as cervical extensors, rotators and lateral inclinators have reduced isometric maximal strength in these patients. In addition, it is unknown if strength measured under different conditions such as rapid movements and considering patients with greater jaw disability would be affected. Future research should look into these issues and clarify the role of maximal strength of cervical muscles in this group of patients.

Maximal cervical flexor muscle strength was not significantly associated with jaw disability, however, a weak association was found between neck disability and maximal cervical flexor muscle strength after adjusting for age, height and weight.

11.6.5 EMG ACTIVITY OF CERVICAL FLEXOR MUSCLES IN PATIENTS WITH TEMPOROMANDIBULAR DISORDERS WHILE EXECUTING THE CRANIOCERVICAL FLEXION TEST (CCFT) COMPARED WITH HEALTHY SUBJECTS

When performing the craniocervical flexion test, no statistically significant differences in electromyographic activity in the sternocleidomastoid muscles or the anterior scalene muscles in patients with mixed and myogneous TMD subjects were found when compared to healthy subjects (p=0.07). **These results do not support the fifth hypothesis of this study** (as stated in chapter 11)**.** However, subjects with TMD had a strong tendency towards clinical significance (reflected by the moderate effect sizes found ranging between 0.42-0.82 which are considered clinically relevant) to have increased EMG activity of the superficial cervical muscles when compared with healthy subjects. The patient groups (i.e. myogenous and mixed TMD) showed greater EMG activity (although not statistically significant) than healthy subjects in the sternocleidomastoid muscles and the anterior scalene muscles for all test conditions (22, 24, 26, 28 and 30mmHg pressure levels) of the CCFT (Figure 9-2, 9-3, and 9-4). This could indicate a different strategy by the subjects with TMD for activating the cervical muscles to stabilize the craniocervical system when compared with pain free subjects.

11.6.6 Endurance of the Cervical Flexor and Extensor Muscles in Patients with Temporomandibular Disorders Compared with Healthy Subjects

Subjects with TMD presented with reduced cervical flexor as well as extensor muscle endurance expressed as a reduced holding time while performing the flexor and extensor muscle endurance tests when compared to healthy individuals supporting the 4th and the 6th hypotheses of this study (as stated in chapter 11). Subjects with mixed TMD, who had more severe jaw pain and jaw disability than the remaining groups had a statistically and clinically lower holding time than healthy subjects and subjects with myogenous TMD in the flexor muscle endurance test. An average of almost 8 seconds difference in holding time (ES: 0.63) between subjects with mixed TMD and healthy subjects and an average of 7 seconds difference between subjects with mixed TMD and those with myogenous TMD were found. This indicated that the endurance capacity of the subjects with more severe jaw pain and disability could be impaired.

Regarding the Neck Extensor Muscle Endurance Test (NEMET), both groups of subjects with TMD (i.e. myogenous and mixed TMD) presented with statistically and clinically significant more reduced holding times than healthy individuals s**upporting the sixth hypothesis of this study.** Subjects with TMD presented an average of 3.5 minutes less holding time than healthy subjects (ES: 0.51 which is considered clinically significant). In addition, patients with mixed TMD presented with steeper negative slopes (although modest) at several times during the NEMET than healthy subjects. This could indicate that cervical extensor muscles of subjects with mixed TMD could have a different pattern of responding to sustained contractions presenting with more fatigue than healthy subjects.

These results highlight the fact that alterations in flexor and extensor endurance capacities could be implicated in the neck-shoulder disturbances presented in patients with TMD.

11.7 CONTRIBUTIONS TO PHYSICAL THERAPY: CLINICAL SIGNIFICANCE OF RESULTS

The results of this project have several implications for the physical therapy field. First of all, they provide a base to promote more research in this area. The preliminary work performed through the systematic review and critical review showed that better designed and conducted studies need to be performed in order to increase the evidence in this area. This project focused mainly in the musculoskeletal impairments of the cervical spine and its link with TMD. However, there are many other areas that need to be explored.

This research project had a strong clinical emphasis. It was designed and developed in order to answer clinical questions. In the area of physical therapy, the treatment of TMD has been mainly based on clinical experiences and the advice of experts in the field. There has been a belief that the cervical spine and TMD are connected in many ways [11] because this connection has been seen clinically.[11] However, there was very little information on how cervical muscles' functioning was related to TMD.

One of the objectives of physical therapy is to restore or rehabilitate the musculoskeletal system using exercises or manual mobilization techniques. Electrophysical modalities are used along with exercises and manual therapy to reduce pain and inflammation. Therapeutic exercises for the masticatory and/or cervical spine muscles are used to improve strength, coordination, resistance, mobility, stability, motor control and endurance of the muscular system.[14] Manual therapy techniques are commonly used to reduce pain and/or restore mobility. The field of therapeutic exercise has grown enormously in physical therapy due to its benefits in chronic conditions. Physical exercise represents a relevant component of rehabilitation for subjects suffering from musculoskeletal pain. Therapeutic exercise has been widely used in a variety of painful musculoskeletal conditions such as low-back pain, shoulder pain, neck pain, patellofemoral pain syndrome, and osteoarthritis to reduce pain and improve function of the musculoskeletal system. [10, 15-17] Besides its effects on function and health, therapeutic exercise is known to have some pain relieving effects. Therapeutic exercise has been seen as the physical therapy treatment with more evidence for treating painful chronic conditions. Therefore, exercise therapy is warranted when managing musculoskeletal pain. In temporomandibular disorders, therapeutic exercise has also been found to have positive results in reducing symptoms of patients with TMD.[10, 18] However, there has been a lack of evidence regarding the best exercises to address these painful conditions and impairments. Although clinical anecdotal experience and basic research have justified the need to address the cervical muscle dysfunction in TMD, research investigating cervical muscle dysfunction in TMD is in its infancy. No study was found that addressed the study of these dysfunctions in subjects suffering from TMD. Thus, the results of this project provide a major contribution to the physical therapy field. Knowing that these cervical muscular impairments could be present in subjects with TMD, would enable clinicians to focus on those impairments and plan a more effective treatment instead of applying a general treatment without targeting these impairments. This could open a new area of research since research investigating the effectiveness of physical therapy programs targeting these impairments needs to be performed.

The specific clinical contributions of this project to physical therapy obtained from each of the areas investigated in this project will be outlined below:

11.7.1 ASSOCIATION BETWEEN JAW DISABILITY AND NECK DISABILITY

This project found that a strong relationship between neck disability and jaw disability due to TMD was present. This result has clinical implications since clinicians need to be aware that not only signs and symptoms between the neck and jaw regions should be considered, but also the level of disability or the impact that these signs and symptoms have on the subjects' lives (i.e. restriction in activities and participation) as measured by some of the tools used in this study (i.e. JFS, NDI, and the level of chronic disability of TMD based on the RDC/TMD [Chronic Pain Grade]). This fact has implications for evaluation and treatment decisions in the area of TMD. It is important for clinicians to know the level of disability of their patients for determining the actions needed to reduce the disability and for planning effective interventions to address both physical and functional impairments. In addition, if patients with TMD have neck disability in addition to jaw disability, physical therapy treatment needs to focus on both areas since the improvement of one could have an influence on the other. Thus, the treatment of a patient with TMD involves a broader management considering not only treatment at the level of the jaw but also treatment involving the whole craniocervicalmandibular system.

The results of this study also indicated that the way one assesses and treats TMD should be reconsidered. This has generated a shift focusing away from signs and symptoms evaluation toward the impact that signs and symptoms have on the function of individuals with pain.[19, 20] The International Classification of Functioning, Disability and Health (ICF) from the World Health Organization (WHO) has been developed to integrate the concepts of disability and function and to create a common language for health professionals who work with disabling conditions such as TMD and chronic pain. Thus, clinicians who work in the area of TMD should be aware that not only should the treatment of signs and symptoms (focused on body structures and body functions) be addressed in subjects with TMD, but the treatment of subject's actual disability should be also addressed. Thus, the use of the ICF framework as well the use of outcomes that evaluate not only body structures or functions but also evaluate the impact of these impairments on subjects' activity and participation as the ones used in this research (i.e. JFS, NDI, and the level of chronic disability of TMD based on the RDC/TMD [Chronic Pain Grade]) need to be covered in this group of subjects. Addressing both issues facilitates the process of evaluation and treatment implementation for patients with TMD, focusing on all aspects of disability (i.e. body structures, body function, activities and participation).[21, 22] In addition, this research highlights the use of well validated outcome measures that address different aspects of disability by clinicians working in this area.

11.7.2 HEAD AND CERVICAL POSTURE AND TMD

It was found that subjects with TMD had neither statistically nor clinically significant differences in most of the head and cervical posture variables when compared with pain free subjects. The association between cervical and head posture in the presence of TMD has been a matter of debate for many years. Physical therapists have commonly used cervical-head posture re-education techniques in order to address postural abnormalities in patients with neck involvement.[23] Postural alterations have been associated with changes in the distribution of loads between the anterior and posterior cervical segments as well as with changes in cervical muscular length.[24] According to the results of the present study along with a current systematic review,[25] there is a lack of a scientific validation of a correlation between postural alteration and TMD. The results of this project indicate that static posture of the craniocervical system in patients with TMD (evaluated through the tragus-C7-horizontal, pogonion-tragus-C7, eye-tragus-horizontal, and tragus-C7-shoulder angles) is not significantly altered and thus static posture evaluation of the craniocervical system is not recommended for these patients. However, it is still unknown whether dynamic posture (i.e. posture that subjects adopt when performing functional activities) is significantly different in subjects with TMD when compared with healthy subjects. Falla et al.,[26] evaluated posture when subjects were performing a functional activity. They found that subtle changes in head/cervical posture over time (about 4°), could reflect poor muscle control of the deep cervical flexor muscles when evaluating sustained postures in patients with pain in the upper quarter. Thus, a more functional evaluation of posture between patients with TMD and healthy controls could provide a better understanding of the muscular impairments of these patients and also explain more accurately the symptomatology in these patients.

According to O'Leary et al.,[23] postural evaluation and treatment could be considered based on individual needs. For example, patients who report posture as an aggravating factor, and who report an improvement of symptoms when performing postural corrections, could use postural correction to improve their symptoms. Thus, clinicians who work with patients with TMD having postural abnormalities as an aggravating factor could consider these recommendations for treating these subjects in clinical practice.

The results of the present study regarding head and cervical posture and TMD helped to clarify and confirm that static posture is not affected in patients with TMD. Also this research recommends that clinicians should move away from static evaluation of posture and consider a more functional evaluation of the head and cervical posture in clinical settings. Thus, more functional impairments could be distinguished in this group of patients and could be treated actively through therapeutic exercises. In addition, this study highlights the need for improving the way that posture is evaluated, incorporating more functional measurements for determining head and cervical posture not only in the sagittal plane but also in coronal and axial plane.

11.7.3 MUSCLE IMPAIRMENTS IN TMD

The study of the cervical muscle dysfunction in subjects with TMD has not been performed previously. There has been a scarcity of information in this area and thus this study contributes with new evidence. The study of muscular impairments in the cervical spine has been a matter of research for many years for musculoskeletal conditions affecting the cervical spine such as neck pain, cervicogenic headache and whiplash associated disorders (WAD). Recent investigations have focused on understanding how pain affects the motor control and muscle functioning in the cervical spine in the presence of chronic pain.[27-37] The "pain adaptation model"[38] explains the interaction between muscle pain and motor control. Motoneurons of the painful agonist are inhibited, while motoneurons from the antagonist muscles are excited (i.e. increase EMG activity) under painful conditions. This results in limitation of movements to prevent further damage. In addition to the pain adaptation model, Sterling[39] has suggested the “neuromuscular pain activation model”. This model proposed that presence of pain leads to inhibition or delayed activation of specific muscles or muscle groups that act in a determined action. Thus, alteration in patterns of muscle activity and recruitment during functional activities occurs under the presence of pain.[39] Generally, the inhibition occurs more frequently in deep spinal muscles which control joint stability.[39] Recently, Murray and Peck [40] have proposed a new model to explain motor changes in presence of pain. They called this model “the integrated pain adaptation model”. This model proposed that complex changes occurred in the whole sensorimotor system in presence of pain and these changes are influenced by individual responses to pain and the complexity of the sensorimotor system. Therefore, changes in muscular activity might involve increase in activity of some muscles and decrease in activity of others irrespective of whether the muscle was being used as agonist or antagonist. In addition, this model highlighted the individual responses to pain. This means that motor responses to pain may be different between individuals. These motor changes occur in an attempt to maintain the homeostasis and to minimize further pain. However, it is possible that these motor adaptations to pain could lead to further pain, injury, and disability.

There is supporting evidence that changes in muscle behaviour and function such as reduced activation of deep cervical muscles, augmented superficial activity of sternocleidomastoid (SCMs) and anterior scalenes (SAs) muscles, and changes in feedforward activation, reduced capacity to relax the cervical muscles, and prolonged muscle activity following voluntary contraction could compromise the control of the cervical spine and consequently lead to pain and dysfunction in the cervical spine.[27-30, 32, 35, 36, 41] Furthermore, it has been shown, through the use of magnetic resonance imaging (MRI), that subjects with pain presented with an alteration in the physical structure of the cervical muscles. These changes included widespread atrophy, pseudo hypertrophy, and fatty replacement of cervical extensor muscles in patients with neck pain. Changes were seen more commonly in the deep cervical muscles such as suboccipital and deep multifidus muscles, but also in superficial layers of semispinalis and capitis muscles.[42-44] Fiber type changes also have been observed in flexor and extensor cervical muscles in patients with cervical pain.[45] All of these changes at the muscular level could be related to the malfunctioning of the cervical system, contributing to the vulnerability of the cervical spine in response to mechanical demands and development of pain. The results of this project are in line with the results obtained by this new research. Although subjects with TMD were found to have no statistically significant increased activity in the superficial cervical muscles when compared with healthy subjects while performing the CCFT, subjects with TMD had a strong tendency towards clinical significance (reflected by the moderate effect sizes (ranging between 0.42-0.82) found which are considered clinically relevant) by the increased EMG activity of the superficial cervical muscles when compared with healthy subjects. Also, other researchers have found that subjects with TMD presented with an increased resting EMG activity of the SCM and upper trapezius muscles when compared with control subjects.[46] These results show a potential change in the motor strategy of the cervical muscles to control the cervical spine in subjects with TMD when compared with healthy subjects. This increased activity in the superficial muscles can be seen as a strategy to compensate for the dysfunction of the deep flexor muscles. This response observed in the present study is in line with the integrated pain adaptation model theory.[40] It has been demonstrated that the loss of selective activation and inhibition of certain muscles that perform synergic action, leads to altered patterns of neuromuscular activation causing loss of joint stability and control. These alterations are initiated by acute pain, but they can persist into the period of chronicity and could be one of the reasons for progression of symptoms.[39] Therefore, it is possible that decreased muscle activation caused by pain could have the potential to affect joint stability in patients with neck involvement.[47-54] As stated by Herzog et al.,[55] "In humans, joint swelling , pain, and stiffness as well as joint instability are often associated with muscle inhibition (p. 305)". This joint inhibition is associated with atrophy and weakness and also with changes in the pattern of contraction of the muscles associated with a joint.[56-58] Moreover, muscle weakness could lead to a diminished capacity for muscular control and early fatigue in daily life activities. Thus, fatigue may cause loss of fine motor control in the cervical system. This has been observed in subjects with painful conditions and is in line with the results obtained by this research. Subjects with TMD presented with reduced endurance of the cervical flexor and extensor muscles expressed as reduced holding time in the cervical flexor and extensor endurance tests as well as presenting with a different pattern of normalized median frequency drop, as evaluated by electromyography, than healthy subjects demonstrating a greater fatigability of the cervical extensor muscles. As discussed earlier, muscles of the spinal system need to be able to meet certain demands for proper functioning of the cervical spine. The cervical column is highly dependent on the support of the cervical muscles. If muscles are prone to fatigue and their performance is impaired, the balance between the extensor and flexor cervical muscles will be interrupted and as a result, improper posture and alignment could lead to cervical dysfunction. Thus, aberrant neuromuscular control of the cervical spine could contribute to irritation of pain-sensitive structures in the neck and contribute to or perpetuate pain in this region. Due to the convergence between the orofacial and cervical region in the trigeminocervical nucleus, pain from any of the upper three cervical synovial joints and muscles innervated by upper spinal cervical nerves could be perceived in regions innervated by the trigeminal nerve and pain from any orofacial structure innervated by the trigeminal nerve could be perceived in cervical regions innervated by the upper cervical nerves. [59-66] Therefore, impaired neuromuscular control in the cervical spine could be related to overload of cervical system and consequently lead to pain in related structures (i.e. cervical muscles, joints, discs, ligaments) which could be referred to the orofacial region.

Thus, if one understands that pain originated and maintained either in orofacial region or cervical region is integrated at the level of trigeminal cervical nucleus (due to convergence) and sent to superior centers where is then modulated through descending mechanisms, one could infer that central sensitization of the caudalis nucleus could affect the motor response of the orofacial muscles as well as the cervical muscles.[67] If trigeminocervical nucleus is sensitized, it could trigger changes in motor activity in the masticatory as well as cervical muscles. These changes could lead to the development of masticatory and cervical muscular dysfunction.

Given the clinically significant results found by this study, the information described above is of importance for clinicians working in this area. It highlights that some important components of proper muscle performance such as the endurance capacity of the cervical flexor muscles and extensor muscles as well as alterations of the fine motor control of the cervical flexor muscles are altered in subjects with TMD. These impairments could make the cervical spine of subjects with TMD more vulnerable to suffer pain since muscles in this region cannot accomplish the demands impose on the cervical spine. Since cervical spine and orofacial region are interconnected, these impairments could be involved in maintaining the cervical spinal dysfunction seen in patients with TMD. Therefore, physical therapists who work with patients with TMD might be able to identify these impairments sooner and could treat them in order to decrease the vulnerability of the cervical spine, contributing to improve the functioning of the craniocervical system in subjects with TMD and subsequently reduce the painful inputs to the trigeminocervical nucleus.

Evidence supports the use of exercises addressing these muscular impairments to reduce symptoms and improve functionality in the craniocervical system in conditions such as chronic neck pain, WAD and cervicogenic headache. [26, 68, 69]. Several clinical trials have been conducted to address muscular impairments in patients with cervical involvement. Training the endurance capacity of the cervical muscles as well as exercises focus on fine motor control through the re-education of normal patterns of contraction have obtained good results in reducing pain and improving function in subjects with these impairments.[68-71] Deep flexor training in patients with cervicogenic headache (CEH) has been shown to decrease pain and the frequency of headaches [69]. The same findings were corroborated by van Ettekoven and Lucas [72] in a sample of subjects with tension-type headache using craniocervical training. In addition, subjects participating in a training program involving craniocervical flexion and cervical flexion exercises improved endurance as well as strength in the cervical flexor muscles after training. [73] Furthermore an endurance program targeting the cervical flexor muscles found that subjects who underwent this type of training improved cervical flexor strength showed reduced myoelectric manifestations of fatigue of the cervical flexor muscles, along with a decrease in pain and disability of the neck. The same effects were found when training the endurance of the cervical extensor muscles in patients with neck pain and subjects with cervical disk disease after anterior cervical decompression and fusion. [74] According to Falla et al.,[68] the improvements in strength and endurance capacities after treatment may be responsible for the reported efficacy of this type of exercise program in musculoskeletal pain conditions. A craniocervical exercise program also has been reported to improve pain intensity and function of the neck.[68] The effects of this program were attributed to an increase in stabilization [75], improvement in motor control of the cervical spine, and an afferent input produced by joint mobilization during the exercises which in turn modulates pain perception at different levels of spinal cord. Thus, these results testing the effectiveness of exercises protocols to improve cervical muscular impairments and consequently decrease pain intensity and improve function are promising and might be translated to the area of TMD. Furthermore, it has been shown that exercises addressed to the neck extensor muscles increased the total neck cross sectional area (CSA) by about 13%. The hypertrophy obtained after training was mainly due to increases in CSA for the splenius capitis (24%), semispinalis capitis (24%), semispinalis cervicis and multifidus muscles (24.9%) after12 weeks of training.[76] Training of the cervical muscles was demonstrated by an increased CSA of the SCM and trapezius muscles as well as a decreased fatigability of the cervical muscles after 8 weeks of training.[77] It is known that an increase in neck muscle size is expected to stabilize the cervical spine and prevent or reduce the severity of cervical impairments and pain. Therefore, there is evidence that treating these impairments found in patients with TMD, through specific and well programmed exercises targeting at cervical muscles can obtain positive effects for stabilization of the cervical system and avoid further injury. Therefore, the information obtained from this research will make physical therapy treatments for TMD based on clinical research evidence and will have a great impact on physical therapy treatments decision and planning.

11.8 STRENGTHS AND LIMITATIONS OF THIS RESEARCH

11.8.1 STRENGTHS

The strengths of this research are as follows:

1. No study was found that investigated any of cervical muscular variables in patients with TMD studied in this project. This study was the first to study cervical muscular impairments in subjects with TMD providing new information and is an initial step in developing this area of research.

2. The sample sizes used for the different studies in this project were large enough to obtain good power. In addition, there was a balanced number of subjects with myogenous and mixed TMD. Most of the studies described previously did not report the power used, using small sample sizes which made the external validity of those results questionable.

3. This study was designed to minimize bias regarding data collection and analytical methods. The data collection procedure followed the same protocol for each subject, a clear clinical diagnosis to determine subjects' symptomatology, and blinding of the individual doing the measurements and statistical analysis were used in this project. Thus, the studies provide a stronger methodology than previous studies investigating the association between CSD and TMD

4. This study used clinical tests along with electromyography to assess the cervical muscular function in patients with TMD. Thus, this study provided a more objective and reliable way of evaluating cervical muscular dysfunction than previous studies.

5. The results of this research provided an important clinical contribution to the area of physical therapy and TMD. It identified impairments in the cervical spine in patients with TMD that could help guide clinicians in the assessment and prescription of more effective interventions addressing these impairments for individuals with TMD.

11.8.2 LIMITATIONS OF THIS RESEARCH

The limitations of this research are as follows:

1. The results obtained in this research are applicable to the group of subjects who participate in this study under the protocols used. They could potentially be applied to subjects with TMD having similar characteristics as the subjects participating in this study. This limitation should be taking into consideration when attempting to extrapolate these results.

2. The use of a convenience sample limits the results of this study. Subjects with TMD were recruited from the TMD/Orofacial Pain Clinic at the School of Dentistry, Faculty of Medicine and Dentistry, and healthy subjects were recruited from students and staff from the University of Alberta. Recruitment of people from other centers and locations could have potentially changed the obtained results of this study. Thus, the

obtained results are applicable to this convenience sample. In addition, only females between 18-50 years of age were recruited for this study. Thus, the results are applicable only to females in this age range and cannot be generalized to all subjects with TMD.

3. It has to be acknowledged that all studies of this project are cross sectional in nature and thus, a cause and effect relationship between the variables studied and TMD cannot be established. It is concluded that cervical muscular impairments are present in subjects with TMD but one cannot say that cervical muscular impairments cause TMD or that TMD caused the cervical muscular impairments.

4. Subjects participating in this research study presented with low levels of jaw disability as well as neck disability. The results obtained in this study are limited by this fact. It is still unknown whether higher levels of disability could be expressed in higher levels of neck muscular impairments as previously observed.[44]

5. This study used specific protocols to evaluate the head and cervical posture, maximal cervical flexor strength, performance of the cervical flexor muscles using the CCFT, and endurance tests to evaluate the cervical flexor and extensor holding times. The results obtained from this research are applicable only to the tests described in the project's protocol. Other testing positions or actions could change the biomechanical behavior of the muscles and could potentially change the study results.

6. This project was also limited by the ability of the researcher to make an accurate diagnosis of the patients. Subjects were classified as having myogenous or mixed TMD. The diagnosis was based on clinical evaluation only and following the guidelines established by the RDC/TMD. There is always a possibility of an incorrect classification, although the evaluator was well trained and has many years of experience in musculoskeletal disorders and evaluating and treating subjects with TMD.

7. Electromyography is a technique that depends on many factors to provide information about muscles and their nerve supply, and of course, has limitations in the interpretation of the end results. The information must be interpreted very carefully according to the limitations of this technique. Technical considerations such as electrode placement, preparation of the skin, amplifier location, and use of filters are very important when using EMG. Therefore, possible contamination of the signals with noise is always an issue and should be considered in the interpretation of the results. In the present study, reliable equipment as well as active electrodes were used which reduced the possibility of noise. In addition, electrode location was performed carefully following well established guidelines to ensure EMG activity quality. There was only one examiner placing the electrodes. Furthermore this examiner was careful to ensure that the same procedure was used for every subject. All of these considerations were

applied in order to ensure contamination of the EMG signals was as little as possible and the analysis of the results more reliable.

8. Analysis of the results could also be a source of bias. However, analysis of the posture, and of the electromyographic variables was performed blinded to subjects group condition. The statistical analysis was also blinded. Blinding the measurements and statistical analytical ensured a better control of analysis bias.

11.9 FUTURE RESEARCH

As mentioned above, this study is at the beginning of an area of research in this area. Some directions for future investigations would be:

1. To study cervical joints dysfunction assessment and treatment and its relationship with craniofacial pain. This study focused only on the evaluation of cervical muscle functioning in subjects with TMD. However, other structures of the cervical spine such as the zygapophyseal joints could also be related to orofacial pain and TMD.

2. To look at multifactorial models involving not only physical factors but also psychological and social factors to explain more efficiently the development and perpetuation of pain in conditions such as TMD. This study focused only in how musculoskeletal impairments in the cervical spine could be related to TMD. However, there are other factors (e.g.

psychological, and social) not explored in this study that can influence the adaptive capacity of subjects to support loads and thus could develop pain.

3. To evaluate dynamic posture is challenging when evaluating the association between posture and painful musculoskeletal conditions such as TMD. As pointed by Kraus,[78] a more functional evaluation such as a dynamic evaluation of the posture between patients with TMD and healthy controls could add to the understanding of the muscular impairments of these patients and also explain more accurately the symptomatology in these patients.

4. To evaluate posture using surface measures in photographs is a field that needs to be better validated.[79]

5. To use electromyography to evaluate fatigue of the cervical flexor muscles in this population to determine whether reduced endurance is present in specific cervical muscles with a more objective tool. This study evaluated the endurance of the cervical flexor muscles using a clinical test.

6. To develop normative values of cervical maximal strength and endurance holding times at different levels of MVC in a representative sample of healthy subjects. Quantitative measures of cervical muscles strength and endurance presented with a large amount of variablity among subjects. This variability could be attributed to different protocols used, sample tested, and also possibly to some anthropomorphic characteristics of the subjects such as age, muscle length and mass, and weight of the limb

(head).[80] Thus, with this variability in mind, it is difficult to determine cut offs for normal values.

7. To clarify whether patients with TMD have impaired rapid force capacity or less adaptability to respond to reflex conditions than healthy subjects. It has been pointed out that patients with chronic pain have an altered pattern of muscle contraction rather than an alteration of maximal effort.[27]

8. To explore the evaluation of maximal strength in other cervical muscle groups such as the extensors, rotators and lateral inclinators and also under different conditions such as rapid movements and in patients with TMD with more severe jaw disability.

9. To investigate structural changes in cervical muscles using mangentic resonance image or ultrasound evaluation in subjects with TMD to help to understand functional changes in cervical muscles seen in this population. This project found some alteration of muscular functioning in subejcts with TMD. It is still unknown if structural changes in cervical muscles are present in subjects with TMD as shown by other studies in subjects with WAD and neck pain conditions.[42-44, 81]

11.10 CONCLUSIONS

Based on the results of this study, the following conclusions can be stated:

1. There was a strong relationship between neck disability and jaw dysfunction in the analyzed sample. This means that in this population of

subjects with mixed TMD, myogenous TMD and healthy subjects, people having greater disability in the neck have greater jaw disability and vice versa.

2. A strong association between the level of chronic disability of TMD (Chronic Pain Grade Disability Questionnaire used by the RDC/TMD) and the neck disability measured through the NDI was found. In other words, a subject with TMD disability of Grade IV (Grade 0-IV), measured using the level of chronic disability of TMD, increase by about 19.32 points on the Neck Disability Index when compared with a person without TMD disability (Grade 0)

3. There were high correlations between Jaw Function Scale, Jaw Disability Checklist, pain intensity, and level of chronic disability of TMD.

4. Good to excellent test-retest reliability was found for the JFS and NDI. This study contributes to increasing the validity evidence of the JFS and NDI in a population of patients with TMD.

5. Craniocervical posture measured using the eye-tragus-horizontal angle showed a significant difference statistically between patients with myogenous TMD when compared with healthy subjects which indicates a more extended position of the head (craniocervical region) in this group of patients. However, the difference was very small (3.3º) and was judged not to be clinically significant. No other postural variables were different statistically between subjects with TMD and healthy subjects. Postural

variables were not significantly related with neck dysfunction, jaw dysfunction and pain intensity.

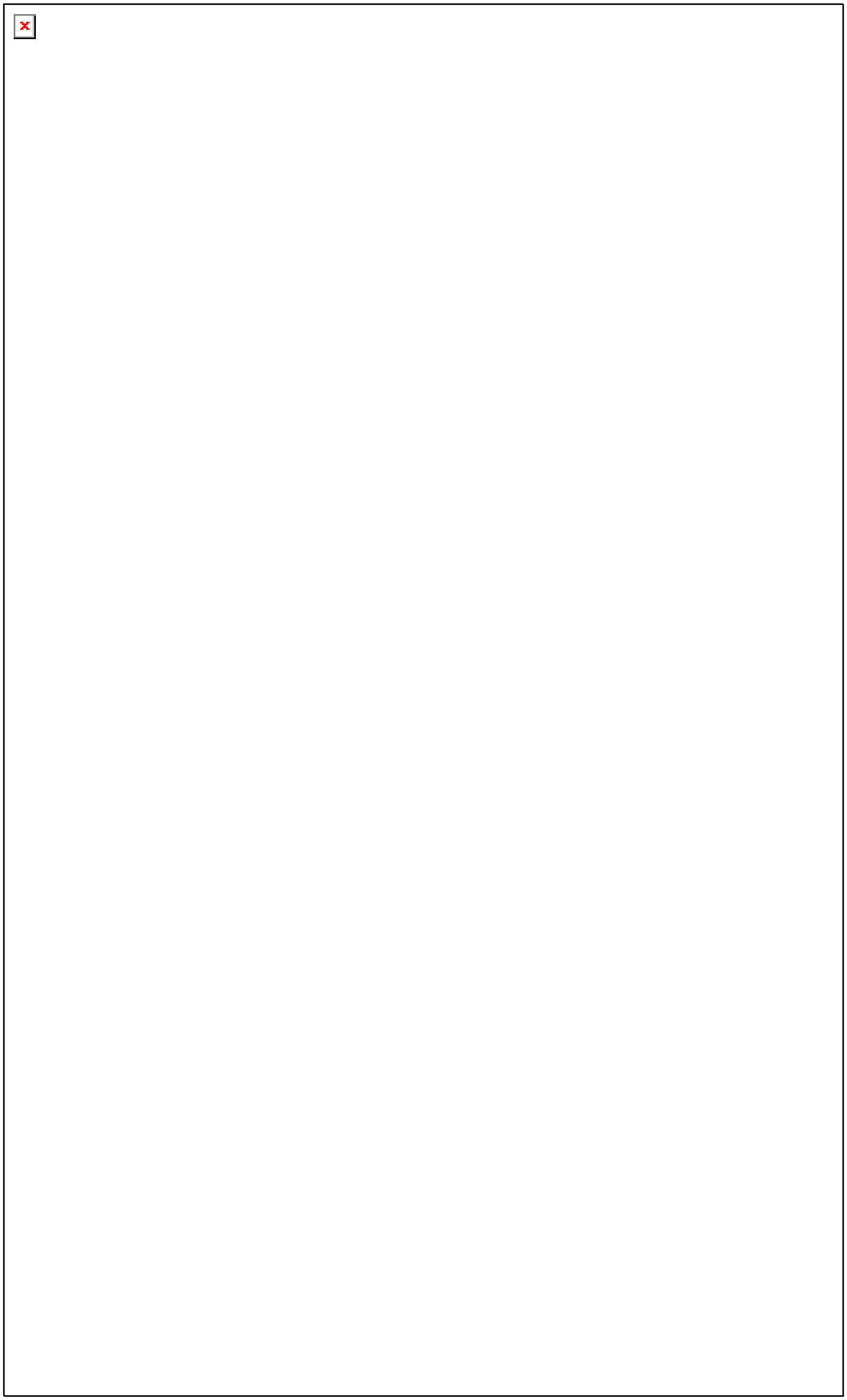
6. Maximal strength of the cervical flexors muscles was found not to be clinically or statistically significant among patients with mixed TMD, myogenous TMD and healthy subjects. No significant association between jaw dysfunction and maximal neck flexor strength was found. A significant but weak association between neck disability and maximal neck flexors strength was found.

7. There was a significant difference in holding time at 25% MVC for the cervical flexor muscles between subjects with mixed TMD when compared with subjects with myogenous TMD and healthy subjects. This implies that subjects with mixed TMD probably had less endurance capacity at lower level of contraction (25% MVC) of the cervical flexor muscles than healthy subjects and subjects with myogenous TMD. No significant associations between neck disability, jaw disability, and clinical variables with neck flexor endurance test were found.

8. There were no statistically significant differences (p=0.07) in electromyographic activity in the sternocleidomastoid muscles and the anterior scalene muscles in patients with mixed and myogneous TMD subjects when compared to healthy subjects when performing the craniocervical flexion test. Moderate and clinically important effect sizes

of comparisons between myogenous TMD and mixed TMD, when compared with healthy subjects while performing the CCFT were found.

9. Subjects with TMD presented with a significantly reduced endurance of the cervical extensor muscles as evaluated by the Neck Endurance Muscle Endurance Test (NEMET) when compared to healthy subjects. In addition, subjects with TMD (i.e. myogenous and mixed TMD) presented with a significantly different pattern of normalized median frequency drop at different times, than healthy subjects as evaluated by electromyography.



				when treating subjects with TMD. Future research should test the effectiveness of this type of program in this group of patients.
Fatigability of the Cervical Extensor Muscles while Doing the Neck Extensor Muscle Endurance Test (NEMET) in Patients With Temporomandibular Disorders.	Cross sectional study	To determine through electromyographic evaluation and through the evaluation of the holding time whether patients with myogenous and mixed TMD have greater fatigability of the cervical extensor muscles (midcervical paraspinal muscles [trapezius, capitis group, and cervicis, group]) when performing a neck extensor muscle endurance test (NEMET) when compared to healthy control subjects.	There were significant differences statistically in holding time and normalized median frequency drop between subjects with TMD when compared with healthy subjects. Subjects with TMD presented with a reduced endurance of the cervical extensor muscles. Subjects with TMD presented an average of 3.5 minutes less holding time than healthy subjects.	The results obtained by this study were evaluated to be clinically important (ES: 0.51). This means that the difference in holding time found among group deserves attention. Thus, clinicians should consider these findings when managing TMD. Endurance capacity of the extensor cervical muscles could be implicated in the neck-shoulder disturbances presented in patients with TMD. These results can help guide clinicians in the assessment of fatigability of the neck extensor muscles and prescribing more effective interventions addressing this impairment for individuals with TMD.

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12 APPENDICES

12.1 APPENDIX 1: ADVERTISEMENT

Do you have pain in your jaw? Or Are you healthy? Are you female?

We need both Normal subjects & those with pain in the Jaw

Are you between 18 and 50 years old?

We invite you to participate in our study. We are evaluating the neck muscles activity in patients with jaw pain. This study will help people who suffer muscular pain in jaw and neck area. The entire procedure would take only one and a half hours.

If you wish participate call 492-2654 or 492-4824, or write an e-mail to Susan Armijo (sla4@ualberta.ca) . You can also go to Corbett Hall and register in room 1- 39.

Thank you in advance.

12.2 APPENDIX 2: EVALUATION FORM TO DETERMINE ELIGIBILITY FOR THIS STUDY FOR HEALTHY SUBJECTS

Appendix 2

Evaluation Form to Determine Eligibility for this Study for Healthy Subjects

Demographic Data

ID ______ Age ______ Date ______

Postural Assessment (in cms.)

Malar sternal relation (maximum 6cm) ______

Apex cervical spine -plome (maximum 12 cm) ______

Functional Range of Motion Cervical Spine and Pain	***Yes***	***No***
• Is the subject able to touch with her chin the superior part of the sternum without pain? (Flexion)	☐	☐
• Is the subject able to locate her head parallel to the ceiling-look at the ceiling-without pain? (Extension)	☐	☐
• Is the subject able to move her nose toward her shoulder rotating her neck without pain? (Both sides) (Rotation)	☐	☐
• Is the subject able to move her head laterally bending her head-neck toward her shoulders without pain? (Both sides)(Lateral inclination)	☐	☐
• Has the subject complained of neck pain constantly or less than 6 months before the evaluation?	☐	☐

Evaluation TMJ	***Yes***	***No***
• Is unassisvted jaw opening and corrected for overbite ≥ 4 cm and without pain?	☐	☐
• Is the palpation of the lateral and dorsal poles of the temporomandibular joint (TMJ) no painful?	☐	☐
• Are compression tests of the TMJ non painful?	☐	☐
• Is the palpation of the jaw muscles non painful?	☐	☐
• Has the subject complained of jaw pain constantly or less than 6 months before the evaluation?	☐	☐

Neurological Evaluation and General Questions	***Yes***	***No***
• Has the subject suffered a stroke or any neurological disease that could interfere with normal functions?	☐	☐
• Is the subject taking antinflammatories drugs or muscular relaxants at the present time?	☐	☐

Observations:

______

______

______

______

______

12.3 Appendix 3: Summary Sheet Inclusion/exclusion Criteria Patients with TMD

Appendix 3

Summary Sheet Inclusion/Exclusion Criteria for Patients with TMD

Personal Data

Name ______ Age ______

Date of birth ______ Patient code ______

History

1. Chief Complaint (Please circle one):
   - i. Muscular TMD
   - ii. Articular TMD
   - iii. Mixed TMD
   - iv. Other: Specify ______
2. Years of complaint: ______
3. Intensity of Pain (VAS): ______
4. Onset: ______
5. Other complaints (Please circle one):
   - a. Neck pain
   - b. Headache
   - c. Shoulder pain
   - d. Back pain
   - e. Other: specify ______
6. Whiplash (Please circle one):
   - a. Yes
   - b. No
7. Medications: (Please list them):

Muscular Evaluation: (Check Painful Muscles)

Muscle	Right	Left
• Temporalis		
1. Anterior	○	○
2. Medial	○	○
3. Posterior	○	○
• Masseter		
1. Superficial anterior	○	○
2. Superficial inferior	○	○
3. Deep	○	○

Checklist for Inclusion	***Yes***	***No***
1. Female between 18-50	☐	☐
2. Pain for at least 3 months	☐	☐
3. Pain not due to recent trauma	☐	☐
4. Pain not due to recent infection	☐	☐
5. Pain not due to an inflammatory cause	☐	☐
6. Score at least of 30mm in VAS	☐	☐
7. Chief complaint in the masticatory muscles	☐	☐
8. Chief complaint in the joint with pain in the TMJ at rest or at function	☐	☐
9. Complaint in the masticatory muscles and TMJ	☐	☐
10. Pain in the lateral pole	☐	☐
11. Pain in the posterior attachment of the TMJ	☐	☐
12. Pain at compression test	☐	☐
13. Pain at retrusion test	☐	☐
14. Clicking with pain	☐	☐
15. Crepitus in the TMJ	☐	☐
16. Pain in the TMJ joint during mouth movements	☐	☐
17. Limited Jaw opening (<40 mm)	☐	☐
18. History of cancer	☐	☐
19. History of bone disease	☐	☐
20. History of neurological disease	☐	☐
21. History of systemic disease	☐	☐
22. Surgery in stomatognathic/cervical system	☐	☐
	☐	☐

Decision: Enter to study

12.4 APPENDIX 4: LETTER INFORMATION TO THE SUBJECTS

UNIVERSITY OF ALBERTA

Information letter

Title of the research project:
"Electromyographic Evaluation of the Cervical Muscular Performance and Fatigability of Cervical Muscles in Patients with Temporomandibular Disorders"

Researchers:
Susan Armijo, PhD student,
Dr. D. Magee, Professor, Department of Physical Therapy.

Purpose/ Background:

Many people have muscle pain in their jaw. The majority of people who have pain in the jaw also have pain in the neck muscles. However, we do not know if neck muscles function properly in people with jaw pain. Thus, in this study, we want to determine if neck muscles have an appropriate function in individuals who have jaw pain when compared with those who do not. Your participation will help us understand if neck muscles are involved in jaw pain and subsequently will help to create a physical therapy treatment using neck muscle training to improve pain and function of the jaw.

Procedure:

You will be screened to ensure that you are eligible to take part in this study. If you meet the inclusion criteria and you agree to participate, you will be asked your age. Your height and weight will be also measured. There will be one visit to our laboratory which will last 2.5 hours. In this visit you will ask to participate in 3 tests.

The skin on your neck will be cleansed with alcohol. This will improve the ability of the electrodes to pick up any activity from a muscle. Then, electrodes will be applied to your neck, and the upper part of your chest with adhesive patches. You will not feel anything through the electrodes. The electrodes, testing devices, and the movements will cause no pain or any injury to your body.

You will be asked to warm up the neck muscles by moving your head in all directions. Straps will then be put over your chest to maintain your position as you lie on a bed for testing.

Test 1

You will be asked to do a nodding movement with your head pushing against a pressure device that will be located between your neck and the bed. You will practice this movement and will be asked to push and hold against the device at five different levels of effort for 10 seconds each while you are doing the nodding movement. A visual feedback device will be located in front of your eyes to tell you when you reach a desired level. You will only have to do a soft nodding movement without pushing the neck too hard forward or backwards. Once you are comfortable with this movement, the test will start. In the test, you will have to maintain the first level for 10 seconds followed by a rest for 30 seconds; then you will maintain the second level for 10 seconds and rest for 30 seconds and so on until you have complete the five levels. You will repeat this procedure of five levels 3 times with a rest period of 3 minutes being used between repetitions to avoid fatigue. A rest period of 10 minutes will be allowed before starting the second test.

Test 2

You will be asked to lie on a bed. Straps will be put around your head to support it. These straps are connected to a device that measures the strength of your neck muscles. You will be asked to push your head and neck forward as hard as you can, and then rest for 3 minutes. You will practice this movement several times before testing begins to ensure you know what to do and are comfortable doing it. Then, you will do the same movement (push your head and neck forward) maintaining 25%, 50% and 75% of your maximal effort. A visual device will give you feedback so that you know when you reach these levels. You will have a rest period of 5 minutes after the first level (25%) and 10 minutes after 50% and 75% levels. A rest period of 10 minutes will be allowed before starting the third test.

Test 3:

You will be asked to lie on your stomach on a bed with your arms and hands beside your body. Straps will be placed around your trunk to support it. The head will be supported initially in the bed. When the test starts the head will be not supported and you have to hold it in horizontal position. A small string will be located around your head. You have to try keeping this string in the same position and not allow it to touch the floor. You have to keep this position as long as you can.

Benefits

There may be no benefit to you personally. However, you will help us to understand if neck muscles are involved in jaw pain. This will help create a physical therapy treatment program for patients with jaw and neck pain and muscle problems.

Risks

There are no known risks involved related to the procedures.

Privacy/ confidentiality:

All data will be kept private, except when codes of ethics or the law requires. The data you give will be kept for at least 7 years after the study is completed. The data will be kept in a safe area (i.e. a locked filing cabinet). Your name or any other identifying data will not be attached to the data you generate by your test. Your name will never be used in any presentations or publications related of the study results. The data gathered for this study may be looked at again in the future to help us answer other study questions. If so, an ethics board will first review the study to ensure that the data are used ethically.

Voluntary Participation:

Your participation is completely voluntary. If at any time you wish to withdraw from the study, you are completely free to do so. You can decide in which test you want to participate in. You do not need to participate in all activities. Only the data that you can provide to us will be used for analysis and there are no consequences if you do not participate in all activities.

Contact information:

If you have any questions, concerns or complaints regarding the study and procedures, please feel free to contact Dr. Paul Hagler (492 9674), Associate Dean –Research in the Faculty of Rehabilitation Medicine.

If you have any questions regarding the study you can contact Ms Susan Armijo (4924824) or Dr. David Magee (492-5765).

12.5 APPENDIX 5: CONSENT FORM

UNIVERSITY OF ALBERTA

Subject consent form

Part 1: Researcher Information

Principal Researcher and Academic Advisor: Dr. David Magee
Name of Co- Investigator: Susan Armijo
Affiliation: Contact Information: 1-39 Corbett -Hall
Email: sla4@ualberta.ca

Part 2: Consent of Subject

	Yes	No
Do you understand that you have been asked to be in a research study?		
Have you read and received a copy of the attached information sheet?		
Do you understand the benefits and risks involved in taking part in this research study?		
Have you had an opportunity to ask questions and discuss the study?		
Do you understand that you are free to refuse to participate or withdraw from the study at any time? You do not have to give a reason and it will not affect your care.		
Has the issue of confidentiality been explained to you? Do you understand who will have access to your records/information?		

Part 3: Signatures

I have read the information sheet and this study was explained to me by:
____
Date: ____

I agree to take part in this study.
Signature of Research Participant: ____

Printed Name: ____

Witness (if available): ____

Printed Name: ____

I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.
Researcher: ____

Printed Name: ____

____
* A copy of this consent form must be given to the subject.

12.6 APPENDIX 6: NECK DISABILITY INDEX

Appendix 6

Neck Disability Index

This questionnaire has been designed to give the doctor information as to how **your neck** has affected your ability to manage in even daily life. Please answer every section and mark in each section only the ONE box which applies to you. We realize you may consider that two of the statements in any one section relate to you, but please just mark the box that which most closely describes your problem **(mark with a "X" in the left side of the option that applies to you)**

Name: ***Date:***

Section 1: Pain Intensity
- ☐ I have no pain at the moment
- ☐ The pain is very mild at the moment
- ☐ The pain is moderate at the moment
- ☐ The pain is fairly severe at the moment
- ☐ The pain is very severe at the moment
- ☐ The pain is the worst imaginable at the moment

Section 3: Lifting
- ☐ I can lift heavy weights without extra pain in my neck
- ☐ I can lift heavy weights but it gives extra pain in my neck
- ☐ Pain prevents me from lifting heavy weights off the floor but I can manage if they are conveniently positioned for example on a table
- ☐ Pain prevents me from lifting heavy weights off the floor but I can manage light to medium weights if they are conveniently positioned
- ☐ I can lift very light weights
- ☐ I cannot lift or carry anything at all

Section 5: Headaches
- ☐ I have no headaches at all
- ☐ I have slight headaches that come infrequently
- ☐ I have moderate headaches which come infrequently
- ☐ I have moderate headaches which come frequently
- ☐ I have severe headaches which come frequently
- ☐ I have headaches almost all the time

Section 7: Work
- ☐ I can do as much work as I want to
- ☐ I can do my usual work but no more (because of neck pain)
- ☐ I can do most of my usual work but no more (because of neck pain)
- ☐ I cannot do my usual work (because of neck pain)
- ☐ I can hardly do any work at all (because of neck pain)
- ☐ I cannot do any work at all (because of neck pain)

Section 9: Sleeping
- ☐ I have no trouble sleeping
- ☐ My sleep is slightly disturbed (less than 1 hour sleepless)
- ☐ My sleep is mildly disturbed (2 hrs sleepless)
- ☐ My sleep is moderate disturbed (2-3 hrs sleepless)
- ☐ My sleep is greatly disturbed (3-5 hrs sleepless)
- ☐ My sleep is completely disturbed (5-7 hrs sleepless)

Score of 50 points

0 - 4	No disability
5 -14	Mild disability
15-24	Moderate disability
25-34	Severe disability
>35	Complete disability

Section 2: Personal Care (dressing, washing, etc)
- ☐ I can look after myself normally without causing extra pain
- ☐ I can look after myself normally but it causes extra pain
- ☐ It is painful to look after myself and I am slow and careful
- ☐ I need some help but manage most of my personal care
- ☐ I need help everyday in most aspects of self care
- ☐ I do not get dressed. I wash with difficulty and stay in bed

Section 4: Reading
- ☐ I can read as much as I want with no pain in my neck
- ☐ I can read as much as I want with slight pain in my neck
- ☐ I can read as much as I want with moderate pain in my neck
- ☐ I cannot read as much as I want because of moderate pain in my neck
- ☐ I can hardly read at all because of severe pan in my neck
- ☐ I cannot read at all

Section 6: Concentration
- ☐ I can concentrate fully when I want to, with no difficulty
- ☐ I can concentrate fully when I want to, with slight difficulty (because of neck pain)
- ☐ I have degree of difficulty in concentrating when I want to (because of neck pain)
- ☐ I have a lot of difficulty in concentrating when I want to (because of neck pain)
- ☐ I have a great deal of difficulty in concentrating when I want to (because of neck pain)
- ☐ I cannot concentrate at all (because of neck pain)

Section 8: Driving
- ☐ I can drive my car without any neck pain
- ☐ I can drive my car as long as I want with slight pain in my neck
- ☐ I can drive my car as long as I want with moderate pain in my neck
- ☐ I cannot drive my car as long as I want because of moderate pain in my neck
- ☐ I can hardly drive at all because of severe pain in my neck
- ☐ I cannot drive my car at all

Section 10: Recreation
- ☐ I am able to engage in all my recreation activities with no neck pain
- ☐ I am able to engage in all my recreation activities with some pain in my neck
- ☐ I am able to engage in most but not all of my usual recreation activities because of pain in my neck
- ☐ I am able to engage in a few of my usual recreation activities because of pain in my neck
- ☐ I can hardly do any recreation activities because of pain in my neck
- ☐ I cannot do any recreation activities at all

12.7 APPENDIX 7: LIMITATION OF DAILY FUNCTION QUESTIONNAIRE FOR PATIENTS WITH TMD (LDF-TMD-JAW FUNCTION SCALE-JFS)

Apendix 7

Limitation of Daily Function Questionnaire for Patients with TMD (LDF-TMD-Jaw Function Scale-JFS-)

This questionnaire has been designed to give the doctor information as to how **"your jaw"** has affected your ability to manage in even daily life. Please answer every section and mark in each section only the ONE box, which applies to you. We realize you may consider that two of the statements in any one section relate to you, but please just mark the box that which most closely describes your problem **(mark with a "X" in the option that applies to you)**

Name: ______ ***Date:*** ______

ITEMS	No problem	Slightly difficult	Moderately difficult	Very difficult	Extremely difficult
• How much does your present jaw problem prevent or limit you for talking for a long period of time including telephone conversations.	○	○	○	○	○
• How much does your present jaw problem prevent or limit you from grinding thin foods.	○	○	○	○	○
• How much does your present jaw problem prevent or limit you from prolonged chewing during meals.	○	○	○	○	○
• How much does your present jaw problem prevent or limit you from activity at home, school, and/or work.	○	○	○	○	○
• How much does your present jaw problem prevent or limit you from clenching teeth when participating in sports (contact teeth together during sports).	○	○	○	○	○
•How much does your present jaw problem prevent or limit you from opening your mouth widely.	○	○	○	○	○
• How much does your present jaw problem prevent or limit you from yawning.	○	○	○	○	○
• How much does your present jaw problem prevent or limit you from brushing your back teeth.	○	○	○	○	○
• How much does your present jaw problem prevent or limit you from falling asleep.	○	○	○	○	○
• How much does your present jaw problem prevent or limit you from sleeping through the night.	○	○	○	○	○

12.8 Appendix 8: History Questionnaire for Jaw Pain

Appendix 8

History Questionnaire for Jaw Pain

Name: ______ *Date:* ______

Could you please fill this form writing in the indicated spaces or write an "X" or highlight the statement that applies to you.

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

	Excellent	Very good	Good	Fair	Poor
1. Would you say your health in general is excellent, very good, good, fair or poor?	○	○	○	○	○
2. Would you say your oral health in general is excellent, very good, good, fair or poor?	○	○	○	○	○

	Yes	No
3. Have you had pain in the face, jaw, temple, in front of the ear or in the ear in the past month?	○	○

[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

	Persistent	Recurrent	One-Time
5. Is your facial pain persistent, recurrent or was it only a one-time problem?	○	○	○

	No	Yes, in the last 6 months	Yes, more than 6 months ago
6. Have you ever gone to a physician, dentist, chiropractor or other health professional for facial ache or pain?	○	○	○

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"?

No pain										Pain as bad 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"?

No pain										Pain as bad 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].

No pain										Pain as bad 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 Change										Extreme Change
○	○	○	○	○	○	○	○	○	○	○
0	1	2	3	4	5	6	7	8	9	10

13. 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 Change										Extreme Change
○	○	○	○	○	○	○	○	○	○	○
0	1	2	3	4	5	6	7	8	9	10

	Yes	No
14. a. Have you ever had your jaw lock or catch so that it won't open all the way?	◯	◯
[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?	◯	◯
15 a. Does your jaw click or pop when you open or close your mouth or when chewing?	◯	◯
15 b. Does your jaw make a grating or grinding noise when it opens and closes or when chewing?	◯	◯
15 d. During the day, do you grind your teeth or clench your jaw?	◯	◯
15 e. Does your jaw ache or feel stiff when you wake up in the morning?	◯	◯
15 c. Have you been told, or do you notice that you grind your teeth or clench your jaw while sleeping at night?	◯	◯
15 f. Do you have noises or ringing in your ears?	◯	◯
15 g. Does your bite feel un- comfortable or unusual?	◯	◯
16 a. Do you have rheumatoid arthritis, lupus, or other systemic arthritic disease?	◯	◯
16 b. Do you know of anyone in your family who has had any of these diseases?	◯	◯
16 c. Have you had or do you have any swollen or painful joint(s) other than the joints close to your ears (TMJ)?	◯	◯
[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?	◯	◯
17 a. Have you had a recent injury to your face or jaw?	◯	◯
[If no recent injuries, SKIP to question 18] *If Yes,*		
17 b. Did you have jaw pain before the injury?	◯	◯
18. During the last six months have you had a problem with headaches or migraines?	◯	◯

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

	Yes	No		Yes	No
a. Chewing	○	○	g. Sexual activity	○	○
b. Drinking	○	○	h. Cleaning teeth or face	○	○
c. Exercising	○	○	i. Yawning	○	○
d. Eating hard foods	○	○	j. Swallowing	○	○
e. Eating soft foods	○	○	k. Talking	○	○
f. Smiling/laughing	○	○	l. Having your usual facial appearance	○	○

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

	Not at all	A little bit	Moderately	Quite a Bit	Extremely
a. Headaches	○	○	○	○	○
b. Loss of sexual interest or pleasure	○	○	○	○	○
c. Faintness or dizziness	○	○	○	○	○
d. Pains in the heart or chest	○	○	○	○	○
e. Feeling low in energy or slowed down	○	○	○	○	○
f. Thoughts of death or dying	○	○	○	○	○
g. Poor appetite	○	○	○	○	○
h. Crying easily	○	○	○	○	○
i. Blaming yourself for things	○	○	○	○	○
j. Pains in the lower back	○	○	○	○	○
k. Feeling lonely	○	○	○	○	○
l. Feeling blue	○	○	○	○	○
m. Worrying too much about things	○	○	○	○	○
n. Feeling no interest in things	○	○	○	○	○
o. Nausea or upset stomach	○	○	○	○	○

	Not at all	A little bit	Moderately	Quite a Bit	Extremely
p. Soreness of your muscles	◯	◯	◯	◯	◯
q. Trouble falling asleep	◯	◯	◯	◯	◯
r. Trouble getting your breath	◯	◯	◯	◯	◯
s. Hot or cold spells	◯	◯	◯	◯	◯
t. Numbness or tingling in parts of your body	◯	◯	◯	◯	◯
u. A lump in your throat	◯	◯	◯	◯	◯
v. Feeling hopeless about the future	◯	◯	◯	◯	◯
w. Feeling weak in parts of your body	◯	◯	◯	◯	◯
x. Heavy feelings in your arms or legs	◯	◯	◯	◯	◯
y. Thoughts of ending your life	◯	◯	◯	◯	◯
z. Overeating	◯	◯	◯	◯	◯
aa. Awakening in the early morning	◯	◯	◯	◯	◯
bb. Sleep that is restless or disturbed	◯	◯	◯	◯	◯
cc. Feeling everything is an effort	◯	◯	◯	◯	◯
dd. Feelings of worthlessness	◯	◯	◯	◯	◯
ee. Feeling of being caught or trapped	◯	◯	◯	◯	◯
ff. Feelings of guilt	◯	◯	◯	◯	◯
gg. Neck pain	◯	◯	◯	◯	◯
hh. Shoulder pain	◯	◯	◯	◯	◯
ii. Back pain	◯	◯	◯	◯	◯

	Excellent	Very good	Good	Fair	Poor
21. How good a job do you feel you are doing in taking care of your health overall?	◯	◯	◯	◯	◯
22. How good a job do you feel you are doing in taking care of your oral health?	◯	◯	◯	◯	◯

23. When were you born? **Month** ____ **Day** ____ **Year** ____

24. Are you male or female? **Male** ____ **Female** ____

25. Which of the following groups best represent your race?

- **Aleut, Eskimo or American Indian** ◯
- **Asian or Pacific Islander** ◯
- **Black** ◯
- **White** ◯
- **Other (please specify):** ____________

26. Are any of these groups your national origin or ancestry?

- **Puerto Rican** ◯
- **Chicano** ◯
- **Cuban** ◯
- **Other Latin American** ◯
- **Mexican/Mexicano** ◯
- **Other Spanish** ◯
- **Mexican American** ◯
- **None of the above** ◯
- **(specify)** ____________

27. What is the highest grade or year of regular school that you have completed?

Never attended or Kindergarten:	00							
Elementary School:	1	2	3	4	5	6	7	8
High School:	9	10	11	12				
College:	13	14	15	16	17	18+		

	Yes	No
28a. During the past 2 weeks, did you work at a job or business not counting work around the house (include unpaid work in the family farm/business)?	◯	◯

[If Yes SKIP to question 29If No,

28b. Even though you did not work during the past 2 weeks, did you have a job or business?	◯	◯

[If Yes SKIP to question 29]
If No,

28c. Were you looking for work or on layoff from a job during those 2 weeks?

- Yes, looking for work ◯
- Yes, layoff ◯
- Yes, both on layoff and looking for work ◯
- No ◯

29. Are you married, widowed, divorced, separated or never been married?

- Married-spouse in household ◯
- Married-spouse not in household ◯
- Widowed ◯
- Divorced ◯
- Separated ◯
- Never Married ◯

30. Which of the following best represents your total combined household income during the past 12 months?

- $0-$14,999 ◯
- $25,000-$34,999 ◯
- $50,000 or more ◯
- $15,000-$24,999 ◯
- $35,000-$49,999 ◯

	Yes	No
31. Have you had a motor vehicle accident OR Whiplash injury?	◯	◯

32. How long ago? ______________

12.9 APPENDIX 9: CHRONIC PAIN GRADE DISABILITY QUESTIONNAIRE.

LEVEL OF CHRONIC DISABILITY DUE TO TMD

Appendix 9

Chronic Pain Grade Disability Questionnaire
Level of Chronic Disability due to TMD

Patient Name/Case # ____________________

Any TMD Pain Reported in the Prior Month? (History Questionnaire, Question 3)

If NO, Graded Chronic Pain (GCP) = 0
If YES, Continue

1. Characteristic Pain Intensity (CPI): (GCP Scale, Questions 1, 2 and 3)
Calculate as follows:

CPI = ________ + ________ + ________ = divided by 3 = ________ x 10 = ____
(Question #1) (Question #2) (Question #3)

2. Disability Points:

A. Disability Days: (GCP Scale, Question 7)

Number of Disability Days = ________
(Question #7)

0-6 days = **0** Disability Points
7-14 days = **1** Disability Point
15-30 days = **2** Disability Points
31+ days = **3** Disability Points

B. Disability Score: (GCP Scale, Questions 4, 5 and 6)

________ + ________ + ________ = ________
(Question #4) (Question #5) (Question #6)

divided by 3 = ________
x 10 = ________

Score of **0-29** = **0** Disability Points
Score of **30-49** = **1** Disability Points
Score of **50-69** = **2** Disability Points
Score of **70+** = **3** Disability Points

________ + ________ = ____ **(Disability Points)**
(Points for Disability Days) (Points for Disability Score)

Chronic Pain Grade Disability Classification (CPGD):

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 > 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

12.10 APPENDIX 10: RDC/TMD JAW FUNCTION QUESTIONNAIRE/ JAW DISABILITY CHECKLIST (JDC).

Appendix 10

Jaw Disability Checklist (JDC)/(RDC/TMD Jaw Function Questionnaire)

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

	Yes	*No*
Chewing	☐	☐
Drinking	☐	☐
Exercising	☐	☐
Eating hard foods	☐	☐
Eating soft foods	☐	☐
Smiling/laughing	☐	☐
Sexual activity	☐	☐
Cleaning teeth or face	☐	☐
Yawning	☐	☐
Swallowing	☐	☐
Talking	☐	☐
Having your usual facial appearance	☐	☐

Total score: Sum of yes responses
Each yes response = 1 point

12.11 APPENDIX 11: LOAD CELL CHARACTERISTICS FOR CERVICAL MUSCLES MVRC EVALUATION

Name: Revere load cell; model: 9363-B10-500-20T1

Specifications:
Rated output: 3mV/V +- 0.0075 mV (actual output supplied with each cell)
Excitation: 10 Vdc (15 Vdc maximum)
Accuracy: 0.037 % full scale
Linearity: 0.03% FS
Hysteresis: 0.02% FS
Repeatability: 0.01% FS
Zero Balance: 1% FS
Creep in 20 min: 0.03% FS
Maximum Load: 200% FS
Construction: Nickel Plated Steel
Cable: 20’ 4 –conductor shielded 22 gage wires.

12.12 APPENDIX 12: BAGNOLI-8 EMG SYSTEM SPECIFICATIONS

Name: Bagnoli-8 EMG System (http://www.delsys.com)

Specifications:

Number of channels	: Eight analog EMG
Overall amplification per channel	: 100, 1000, 10000
Max. output voltage range	: ± 5 volts
Channel frequency response	: 20± 5 Hz to 450± 50 Hz, 12 dB/octave
EMG electrodes	: DE-2.1 (single differential)
Electrode CMRR	: 92 dB
System noise	: < 1.2 µV (rms) for the specified bandwidth
Power requirements	: 12 VDC, 120mA
Channel output isolation	: 3750 V (rms) at 60Hz fro 60 sec.
Signal quality check	: line frequency interference (50 or 60Hz) Channel saturation check (± 4.8 V threshold)
Signal quality warning	: Red LED, selectable audio buzzer
Operating Temperature	: 15º to 40º C or 59º F to 104º F
Case dimensions	: 205mm x 108mm x 44mm 8.08"4.26" x 2.25"
Weight	: 511 grams, 1.1 lbs

12.13 APPENDIX 13: ELECTRODES SPECIFICATIONS

Name: DE-2.1 Electrodes (http://www.delsys.com)

Specifications:

Electrode contacts	: 2 silver bars 10 mm x 1 mm diameter 0.394" x 0.39" diameter
Contacting space	: 10mm 0.394" Single differential configuration
Electrode dimension	: 19.8 mm x 5.4 x 35 mm
Preamplification	: 10
Bandwidth	: DC- 700kHz
CMRR	: 92 dB
Noise (RTI)	: < 1.2 µV (rms) for the specified bandwidth
Power	: ± 6 volts at 2.3 mA (maximum), at 1.8 mA (quiescent)
Cable length	: 1.67 m
Connector	: Hypertronics
Numbers of conductors	: 4 (shielded)
Case material	: polycarbonate plastic

12.14 APPENDIX 14: AIR PRESSURE FEEDBACK

<u>Name</u>: Dwyer Magnehelic® differential pressure gage

<u>Specifications:</u>

Service	: air and non-combustible gases
Housing	: die cast and aluminum case with bezel and acrylic cover. Exterior finish is coated gray to withstand 168 hours salt spray corrosion test
Accuracy	: ± 2% full scale (± 3% on-0 and 4% on -00 ranges) throughout range at 70º F (21.1 º)
Pressure Limits	: -20 Hg to 15 psig
Overpressure	: Relief plugs open at approximately 25psig (1.72KPa)
Temperature limits	: 20 to 140ºF (-6.67 to 60ºC)
Size	: 4" (101.65mm)
Weight	: 1 lb 2 oz (510 g)

12.15 APPENDIX 15: MINIATURE PRESSURE CELL

Name	: Miniature pressure cell, FPN-07PG Fujikura Ltd.
Model/Rated pressure	: 02PG, 05PG, 07PG, 15PG unit
Pressure type	: Gauge pressure
Rated pressure	: 13.79, 34.47, 48.26, 103.4 kPa
Rated pressure	: 0.141 0.352 0.492 1.055 kg/cm2
Measurable pressure range	: [-13.79-13.79],[- 34.47-34.47]; [48.26- 48.26]; [-98.07-103.4] kPa
Pressure media	: Non-corrosive gas
Excitation current(Constant)	: 1.5 mADC
Maximum load pressure	: Twice of rated pressure
Maximum excitation current	: 3.0 mADC
Operating temperature	: 0-80 C°
Storage temperature	: 20-100 C°
Operating humidity	: 30-80(No dew condensation) % RH

Electric performances/characteristics (Excitation current I=1.5mA constant, Ambient temperature Ta=25)

Full scale span voltage	: 40-130 mV
Offset voltage	: 40-25 mV
Bridge impedance	: 4000 6000

Mechanical response time 2(For the reference) msec, Accuracy

Temperature sensitivity of offset(TSO)	: 10.0 8.0 FS/0 50
Temperature coefficient of sensitivity(TCS)	: 5.0 2.5 FS/0 50
Linearity:	: 0.6 0.3 FS
Pressure hystersis	: 1.0 0.7 FS