Cervical Musculoskeletal Impairments and Temporomandibular Disorders

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ABSTRACT

Objectives: The study of cervical muscles and their significance in the development and perpetuation of Temporomandibular Disorders has not been elucidated. Thus this project was designed to investigate the association between cervical musculoskeletal impairments and Temporomandibular Disorders.
Material and Methods: A sample of 154 subjects 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.
Results: A strong relationship between neck disability and jaw disability was found (r = 0.82). Craniocervical posture was statistically different between patients with myogenous Temporomandibular Disorders (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.
Conclusions: Subjects with Temporomandibular Disorders presented with impairments of the cervical flexors and extensors muscles. These results could help guide clinicians in the assessment and prescription of more effective interventions for individuals with Temporomandibular Disorders.

Keywords: temporomandibular disorders; neck; cervical spine; mucosceletal diseases impairments; physical therapy techniques.

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INTRODUCTION

Temporomandibular Disorders (TMD) are considered to be a major public health problem as they are the main source of chronic orofacial pain and the most prevalent category of nondental chronic pain conditions in the orofacial region [1]. They 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]. In addition, TMD have been considered to have a great economic impact due direct care [2] and have been shown to have similar individual impact and burden as back pain and severe headache [2].

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 and decrease patients' symptomatology such as medications, occlusal splint therapy, physical therapy, psychotherapy, acupuncture, and behavioral therapy interventions. To date, 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 [3,4].

From the physical therapy (PT) point of view, TMD and its associated impairments has been an area of concern for many years since PT is commonly used to treat the physical impairments presented by patients with TMD and orofacial pain. PT treatment for TMD addresses many different areas being used to relieve pain in the temporomandibular joint (TMJ) and masticatory muscles, and in the surroundings tissues (i.e. cervical joints and cervical muscles), to improve TMJ and cervical range of motion as well as improve function of the masticatory and craniocervical systems using physical modalities, exercises, and manual therapy 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, PT treatment has focused on improving craniocervical muscular equilibrium. PT clinicians generally teach 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. Therefore, the PT area is closely involved with the treatment of TMD, and consequently has been involved in looking at better methods to diagnose or recognize physical impairments in patients suffering from this condition to provide more effective treatment options to these patients. 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 Cervical Spine Dysfunction (CSD) [5].

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 investigated. Most of the current evidence supporting the relationship between neck and craniofacial pain came from studies with low levels of evidence (Sackett levels 3, 4 and 5), and lacking of scientific rigor [5]. However, the available research pointed out a tendency to link cervical spine and supporting structures with craniofacial pain. Furthermore, the association between head and cervical posture and TMD has been inconclusive due to a lack of high quality research and thus no clear information regarding the connection between neck and head posture and TMD has been evidenced [6]. In addition, the results of a systematic review investigating PT interventions for TMD found that exercises used to improve cervical mobility and functioning and improve head and cervical posture decreased the symptoms in patients with TMD [3]. However, the research into exercises used to treat posture and improve mobility and function in patients with TMD has lacked a clear exercise prescription (i.e. type of exercise, muscles targeted, dosage, frequency) as well as a clear underlying mechanism of why these exercises, directed toward to the neck, improved TMD symptoms.

It was evident to the research team that the evidence supporting PT 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 postural retraining and the cervical 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 potentially 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 their strength, performance (evaluated through the craniocervical flexion test [CCFT]), or endurance capacities for both flexor and extensor cervical muscles in patients with TMD. Without knowledge of these impairments, clinicians treating the cervical spine and its muscles in patients with TMD have commonly planned exercises for the cervical spine muscles based on their intuition, their own experience, but without clear scientific evidence for exercise prescription. Thus, treatment for patients with TMD was more trial and error leading to more time and resources being spent to determine which exercises were more appropriate for this condition. Therefore, the overall aim of this research project was to determine the extent of cervical musculoskeletal impairments in patients with Temporomandibular Disorders, specifically looking at alterations in head and cervical posture, maximal isometric cervical flexor muscle strength, isometric cervical muscle endurance, performance of the cervical flexor muscles (as evaluated by the CCFT) as well as the presence of neck disability in patients with TMD. Identifying cervical musculoskeletal impaiments in patients with TMD could help guide clinicians in their assessment and treatment in patients with TMD.

Research questions

The following research questions guided this project:
1. Was there any relationship between neck disability and jaw disability?
2. What kind of cervical involvement was present in patients with TMD?
   a) Did subjects with mixed and myogenous TMD present with altered head and cervical posture when compared with healthy subjects?
   b) Did subjects with myogenous and mixed TMD have reduced maximum isometric cervical flexor muscle strength when compared with normal subjects?
   c) Did subjects with myogenous and mixed TMD have reduced cervical flexor muscle endurance when compared with normal subjects?
   d) Did subjects with myogenous and mixed TMD have altered cervical flexor muscle performance (as evaluated by the CranioCervical Flexion Test-CCFT) when compared with normal subjects?
   e) Did subjects with myogenous and mixed TMD have reduced cervical extensor muscle endurance while performing the Neck Extensors Muscular Endurance Test (NEMET) when compared with normal subjects?
3. Were the results obtained clinically relevant?

MATERIAL AND METHODS

The present project consisted of 6 studies and was conducted with the objective of overcoming some of the limitations and shortcomings found in the available literature. The studies were designed to minimize bias regarding data collection and analytical methods. The data collection procedures 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, thereby providing a stronger methodology than previous studies investigating the association between CSD and TMD.

The first of these studies explored the association between neck and jaw disability using validated and recognized tools such as the Neck Disability index (NDI) [7,8], the "Limitations of Daily Functions in TMD Questionnaire" (LDF-TMDQ or Jaw Function Scale-JFS) [9], and the Level of Chronic TMD Disability based on the RDC/TMD (Chronic Pain Grade Disability Questionnaire) [10]. Previous studies established the association between jaw pain and neck pain through the presence of signs and symptoms, however, no 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 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 aimed at determining which cervical musculoskeletal impairments were present in subjects with TMD. It was felt that information regarding these cervical physical impairments could add to the scarcity of knowledge in this area and would identify sources of dysfunction in patients with TMD allowing more effective treament options more readily implemented by PT clinicians.

A sample of 154 subjects participated in this project. Subjects with TMD (i.e. myogenous and mixed TMD) were compared with healthy subjects for the following variables: head and neck posture, maximal isometric cervical muscle strength, isometric cervical flexor and extensor muscles endurance, and cervical flexor muscle performance (as evaluated by the CCFT). More details about inclusion and exclusion criteria, data collection, and set up of the experiments can be found elsewhere [11-17].

Healthy subjects were recruited from students and staff at the University of Alberta. Subjects with TMD were recruited over a 2 year period from the TMD/Orofacial Pain Clinic at the Department of Dentistry, Faculty of Medicine and Dentistry, University of Alberta.

All subjects (i.e. healthy and subjects with TMD) were evaluated by an experienced PT to determine inclusion and exclusion criteria for the studies.

In addition important clinical information was collected from the participants (e.g. onset, duration of symptoms, treatments received). In addition subjects were asked their intensity of pain (VAS) [18,19], and to complete the Neck Disability Index (NDI) [7,8], the Jaw Function Scale (LDF-TMDQ/JFS) [9], the Jaw Disability Checklist (JDC) used by the RDC/TMD, and the Graded Chronic Pain Questionnaire of TMD used by the RDC/TMD [10,20] to evaluate chronic disability due to TMD. All of these scales have been considered valid and reliable.

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 1. Subjects were asked to read an information letter and signed an informed consent in accordance with the University of Alberta's policies on research using human subjects.

A brief description of the analyzed variables is as follows:

Head and cervical posture

Head and neck posture were measured using a lateral photograph, taken with the head in the self-balanced position [21,22]. Four angles were measured on the photographs: 1) eye-tragus-horizontal, 2) tragus-C7-horizontal, 3) pogonion-tragus-C7, and 4) tragus-C7-shoulder using Alcimagen software® [23,24]. All of the measurements were performed by a single trained rater (a dentist specializing in orthodontics), blinded to the subjects' group status, following the same procedure for all photographs. More details about the procedure can be found in Armijo-Olivo et al. (Figure 1) [13].

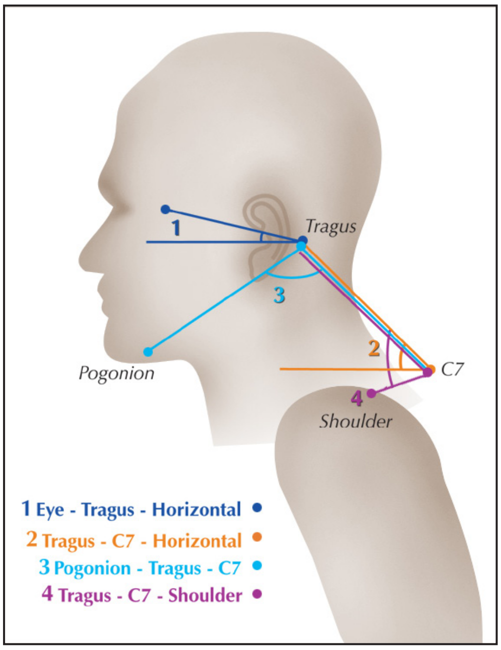

Figure 1. Postural variables analyzed in this project.

Maximal isometric cervical flexor strength

Maximal isometric cervical flexion strength was measured with the subjects in supine lying using a device attached to a plinth and connected to a visual feedback screen. This device contained a load cell to register the isometric strength generated by the subject during the procedure. The average value of strength of the 2 contractions registered was used as the maximal voluntary contraction (MVC). More details can be found in Armijo-Olivo et al. (Figure 2) [16].

Isometric endurance of the cervical flexor muscles

The isometric endurance of the cervical flexor muscles was performed in the same supine position using the same equipment described for the evaluation of the flexor MVC. After performing the MVC, each subject was asked to perform two submaximal isometric cervical flexion contractions at 25% MVC, 50% MVC, and 75% MVC, keeping the chin retracted, and to maintain these contractions as long as possible using a visual display for feedback of the force output. The holding time during the cervical flexion movement at different levels of contraction was registered and analyzed. The test was stopped when 1) the subject could not maintain the desired target strength level (i.e. percentage MVC) determined for the test, or 2) the subject complained (self-reported) of an unacceptable pain during the test or the training stage (Figure 2) [12].

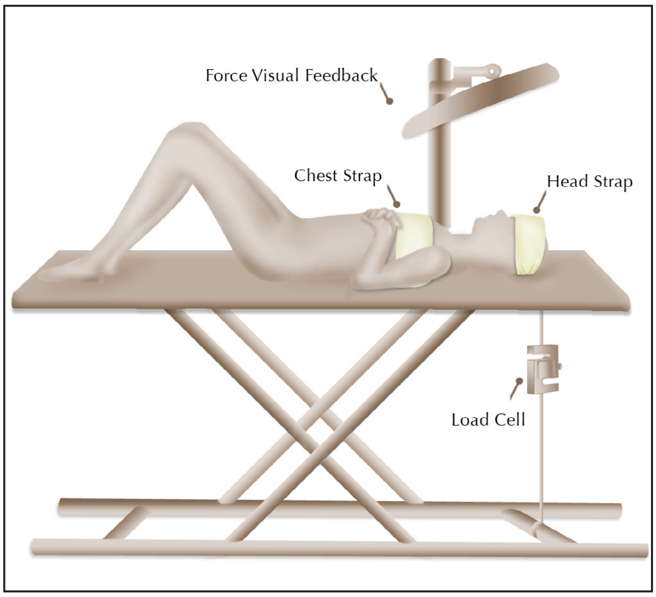

Figure 2. Set up for measuring maximal voluntary strength and endurance of the cervical flexor muscules.

Table 1. Summary of studies' characteristics and main results performed in this project

Study	Design	Main objectives	Results: Statistical significance	Clinical significance: effect size (ES) and minimal important differences (MID)	Clinical implications
The Association between Neck Disability and Jaw Disability	Cross sectional study	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) and the level of chronic disability of TMD based on the RDC/TMD (Chronic Pain Grade Disability Questionnaire).	A strong relationship between neck disability and jaw disability was found (r = 0.82, P < 0.05). 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.	The obtained effect size was 0.82 (correlation coefficient).	The effect size of the association (ES: 0.82) between JFS and NDI is clinical significant. These results indicate that 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 in the other.
Head and Cervical Posture in Patients with Temporomandibular Disorders (TMD)	Cross sectional study	The main objective of this study was to determine whether patients with myogenous and mixed TMD had different 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.	Craniocervical posture measured using the eye-tragus-horizontal angle was significantly different (statistically) between patients with myogenous TMD when compared to healthy subjects (3.3°, [95% CI 0.15, 6.41] P = 0.036). This indicates a more extended position of the head (craniocervical region) in this group of patients.	The calculated ES for the difference between subjects with myogenous TMD and healthy subjects in craniocervical posture (eye-tragus-horizontal angle) was 0.46. The calculated MIDs for the eye-tragus-horizontal angle were1.08° and 2.70° using 0.2 and 0.5 effect sizes respectively for the calculation [28].	The difference in the eye-tragus-horizontal angle between patients with myogenous TMD and healthy subjects was very small (3.3°) and was judged to be not clinically significant based on clinical judgment 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 [28]. According to the results of this study, static posture evaluation of the craniocervical system is not recommended in these patients. Clinicians should consider a more functional evaluation of the head and cervical posture in clinical settings to determine functional impairment of these subjects. Better ways to evaluate functional posture are needed.
Maximal Strength of the Cervical Flexor Muscles in Patients with Temporomandibular Disorders	Cross sectional study	To determine whether there was a difference in maximal cervical flexor strength in subjects with TMD (mixed and myogenous TMD) when compared to healthy subjects.	There was no statistically or clinically significant difference in maximal cervical flexor muscle strength among groups (P > 0.05) when adjusted by body weight. Average differences in maximal cervical flexor muscle strength between healthy and subjects with TMD ranged between 3.73 and 4.45 Newtons ([95% CI -9.9, 2.4 (Newtons)] between mixed TMD vs. healthy subjects, and [95% CI -10.3, 1.4 (Newtons) between myogenous TMD vs. Healthy subjects).	The ES of the differences between Patients with TMD and healthy were between 0.25 - 0.30. The MIDs in cervical flexor strength ranged between 3.0 and 7.50 Newtons using 0.2 and 0.5 effect sizes respectively for the calculation [28].	The effect sizes reached by the differences in maximal cervical flexor muscle strength among groups were estimated to be small (ES: 0.25 - 0.30). This indicated that the differences found between healthy subjects and subjects with TMD are not clinically relevant. The results highlight that probably maximal isometric cervical flexor strength is not altered in patients with TMD. 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 condition such as rapid movements and 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 this group of patients.
Electromyographic Evaluation of the Performance of Cervical Flexor Muscles in Patients with Temporomandibular Disorders while Executing the Craniocervical Flexion Test (CCFT)	Cross sectional study	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.	There were marginally no statistically significant differences (P = 0.07) in electromyographic activity in the sternocleidomastoid muscles or the anterior scalene muscles in patients with mixed and myogneous TMD subjects when compared to healthy subjects when performing the craniocervical flexion test. Mean differences in EMG activity between subjects with TMD and healthy subjects ranged from 1.6% to 12.1% MVC.	The effect sizes of the differences in EMG activity of the SCM and AS muscles, moderate effect sizes ranging from 0.42-0.82 in many of the comparisons between subjects with TMD and healthy subjects were found. The minimal important differences in EMG activity of the cervical flexor muscles while performing the CCFT ranged between 1.8 - 4.9% MVC and between 4.6 - 12% MVC using 0.2 and 0.5 effect sizes respectively for the calculation [28].	Subjects with TMD had a strong tendency to have increased EMG activity of the cervical superficial muscles when compared with healthy subjects. These results are of clinical relevance (reflected by the moderate-high effect sizes found ranging between 0.42 - 0.82) This could indicate a different strategy to activate cervical muscles to stabilize the craniocervical system when compared with pain free subjects. Clinicians and researchers should acknowledge the clinical significance of these results. Thus, exercise programs addressing these abnormal motor patterns could be of value when treating subjects with TMD. Future research should test the effectiveness of this type of program in this group of patients.
Endurance of the Cervical Flexor Muscles in Patients with Temporomandibular Disorders	Cross sectional study	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.	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 (P < 0.05). Subjects with mixed TMD had an average of almost 8 seconds (95% CI 2.7, 12.4, seconds) of difference in holding time when compared with healthy subjects and an average of 7 seconds (95% CI 2.4, 11.8, seconds) of difference when compared with myogenous TMD.	The calculated effect sizes of the differences ranged between 0.60-0.63 (moderate effect sizes). The MIDs in holding time ranged between 2.36 and 5.94 seconds using 0.2 and 0.5 effect sizes respectively for the calculation [28].	The effect sizes found for these differences (ES: 0.60 - 0.63) were considered clinically relevant. This implies that subjects with mixed TMD 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.
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 statistically significant differences in holding time and normalized median frequency drop between subjects with TMD when compared with healthy subjects (P < 0.05). Subjects with TMD presented with a reduced endurance of the cervical extensor muscles. Subjects with mixed TMD presented an average of 3.45 minutes (207 seconds) less holding time than healthy subjects (95% CI 39.8, 374.2 seconds) and subjects with myogenous TMD presented an average of 3.5 minutes (211 seconds) less holding time than healthy subjects (95% CI 51.6, 370.5 seconds).	The calculated effect sizes of the differences ranged between 0.50 - 0.52 (moderate effect sizes) [28]. The minimally important differences in holding time ranged between 1.36 minutes (81.6 seconds) and 3.4 minutes (204 seconds) using 0.2 and 0.5 effect sizes respectively for the calculation [28].	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.

ES = effect size; MIDs = minimal important differences.

Isometric endurance of the cervical extensor muscles during the neck extensor muscle endurance test (NEMET)

The isometric endurance of the neck extensor muscles was measured using the neck extensor muscle endurance test (NEMET). Subjects were asked to maintain a prone position on a plinth with the head and neck unsupported over the end of the plinth with the arms alongside the trunk. Endurance holding time was measured with a stopwatch after removing the neck support and asking the subject to hold the position of the head steady with the chin retracted and the cervical spine horizontal to the floor (Figure 3) [25].
The test was discontinued if [26]:
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).

Performance of the superficial cervical flexor muscles: electromyographic (EMG) activity of the cervical flexor muscles during the craniocervical flexion test (CCFT)

The performance of the superficial cervical flexor muscles was evaluated through the craniocervical flexion test (CCFT) [27]. The CCFT required each subject to perform the craniocervical flexion movement in five progressive stages of increasing pressure (between 22 and 30 mmHg) with the aid of a visual feedback device [27]. The electromyographic activity of the sternocleidomastoid and anterior scalenes (right and left) was collected during the CCFT (Figure 4). Elevated electromyographic activity of the superficial cervical muscles (sternocleidomastoid and anterior scalenes) may be a compensation for reduced or impaired activity of the deep cervical flexor muscles in subjects with cervical associated pain compared to healthy individuals [27].
To obtain a measure of EMG amplitude, maximum root mean square (RMS) was calculated for 4 seconds during the 10-second submaximal contractions for each muscle while doing the CCFT using IGOR Pro 5.1 and was expressed a percentage of the 3 sec EMG activity obtained during the MVC normalization procedure [14,25].

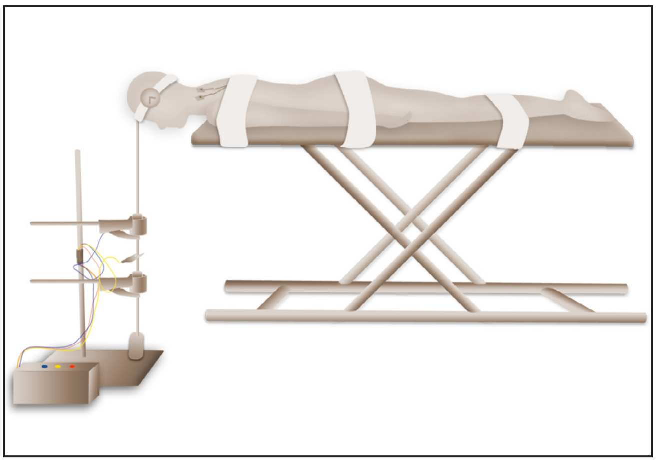

Figure 3. Neck extensor muscle endurance test (NEMET).

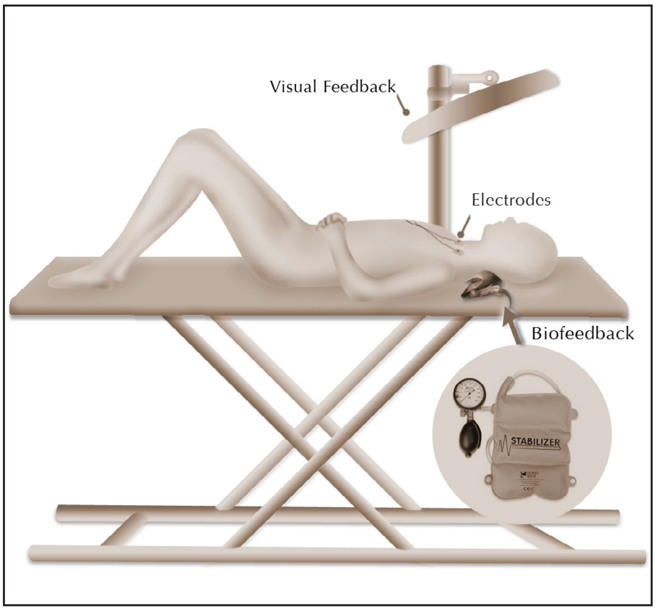

Figure 4. Craniocervical flexion test.

Statistical analysis

Several analyses were used in the project. Simple and multiple regression analyses were used to determine the association between jaw and neck disability and the chronic disability classification used by the RDC/TMD and neck disability respectively (research question 1). A one way MANOVA test was used to analyze the difference between postural angles among groups (research question 2a). A one-way ANCOVA analysis was used to analyze the differences in maximal isometric flexor strength among groups adjusted by body weight (research question 2b). Repeated measures ANCOVA test was used to analyze the difference in holding time obtained for the cervical flexor muscles at different levels of contraction among groups adjusted by body weight (research question 2c). A three-way mixed design ANOVA with repeated measures was used to evaluate differences among groups in the cervical flexor performance during the craniocervical flexion test (research question 2d). A one way ANOVA test was used to evaluate the differences in cervical extensor holding time between subjects with TMD and healthy subjects (research question 2e). The evaluation of clinical relevance of the results was performed based on the effect size (ES), Minimal Important Differences (MIDs), and clinical judgement (research question 3). Detailed information regarding these methods of analysis can be found elsewhere [28].

RESULTS

The main results of this research were as follows (Table 1):

Relationship between jaw disability and neck disability

A strong association between neck disability and jaw disability in the studied population was found (r = 0.82) although no cause and effect was determined. The effect size of the association (ES: 0.8) between JFS and NDI was high, indicating a relevant finding for 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 (which has a maximum of 50 points) when compared with a person without TMD disability.

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. However, the difference between the two groups was small (3.3º) [95% CI 0.15, 6.41 P = 0.036] and these results were considered to have no clinical relevance based on clinical judgment since it is very unlikely that such a small difference, as the one found in this study, would be used by a clinician as a criterion for determining progression or change in posture. 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.

Maximal isometric cervical flexor muscle strength in patients with TMD and healthy subjects

Maximal isometric cervical flexor muscle strength was not statistically or clinically different between patients with TMD and healthy subjects. Average differences in maximal isometric cervical flexor muscle strength between healthy and subjects with TMD ranged between 3.73 Newtons ([95% CI - 9.9, 2.4 (Newtons)] and 4.45 Newtons [95% CI - 10.3, 1.4 (Newtons)] between mixed TMD vs. healthy subjects and between myogenous TMD vs. healthy subjects respectively. The effect sizes reached by these values were estimated to be small (ES: 0.25 - 0.30). Furthermore, the calculated mean difference values between groups were lower than the MID calculated values (3.0 and 7.50 Newtons) indicating that the differences found among groups were not clinically relevant. Thus, maximal isometric cervical flexor muscle strength is not reduced in subjects with TMD in this population when compared with healthy subjects.

Performance of cervical flexor muscles in patients with TMD while executing the craniocervical flexion test (CCFT) compared with healthy subjects

Subjects with TMD had no statistically significant differences in EMG activity of the superficial cervical muscles (SCM and AS) when compared to healthy subjects (P = 0.07), although important effects sizes reflecting a clinically relevant difference between the two groups were found (effect sizes ranging between 0.42 - 0.82) [28]. Mean differences in EMG activity between subjects with TMD and healthy subjects ranged from 1.6% to 12.1% MVC. The minimal important differences in EMG activity of the cervical flexor muscles while performing the CCFT ranged between 1.8% to 12% MVC. Several calculated mean differences from different muscles [i.e. sternocleidomastoid and anterior scalenes (right and left)] and conditions during the test (i.e. pressure levels between 22 and 30 mmHg) between subjects with TMD and healthy subjects over passed values of MIDs between groups indicating a clinical relevant finding [14,28]. Although variability of the electromyographic activity was high, patient groups (i.e. myogenous and mixed TMD) showed greater EMG activity than healthy subjects in the sternocleidomastoid muscles and the anterior scalene muscles for all test conditions (22, 24, 26, 28 and 30 mmHg pressure levels) of the CCFT demonstrating an abnormal pattern of contraction.

Isometric endurance of the cervical flexor and extensor muscles in patients with TMD compared with healthy subjects

Subjects with TMD also presented with reduced isometric cervical flexor as well as isometric extensor muscle endurance expressed as a reduced holding time while performing the flexor and extensor muscle endurance tests when compared to healthy individuals. 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 (95% CI 2.7, 12.4 seconds) (ES: 0.63) between subjects with mixed TMD and healthy subjects and an average of 7 seconds (95% CI 2.4, 11.8, seconds) difference between subjects with mixed TMD and those with myogenous TMD were found. The estimated difference between groups (TMD and healthy subjects) was higher than the calculated MIDs in holding time which ranged between 2.36 and 5.94 seconds. This indicated that the isometric endurance capacity of the subjects with more severe jaw pain and disability could be impaired.

Both groups of subjects with TMD (i.e. myogenous and mixed TMD) presented with statistically significant and clinically relevant reduced holding times than healthy individuals when doing the Neck Extensor Muscle Endurance Test (NEMET). Subjects with TMD presented on average less holding time than healthy subjects (mean difference = 207 seconds; 95% CI [39.8, 374.2] between subjects with mixed TMD vs. healthy subjects; and mean difference = 211 seconds; 95% CI [51.6, 370.5] between subjects with myogenous TMD and healthy subjects). These values were higher than the calculated MIDs for holding time which ranged between 81.6 seconds and 204 seconds. The calculated effect sizes of the differences ranged between 0.50 - 0.52 which are considered clinically relevant.

These results highlight the fact that alterations in isometric flexor and extensor endurance capacities could be implicated in the neck-shoulder disturbances presented in patients with TMD.

DISCUSSION

Contributions to physical therapy: clinical relevance of the results

This research project had a strong clinical emphasis. It was designed and developed in order to answer clinical questions. In the area of PT, the treatment of TMD has been mainly based on clinical experience and expert advice. There has been a belief that the cervical spine and TMD are connected in many ways because this connection has been seen clinically [5]. However, there was very little information on how cervical muscles function was related to TMD.

One of the objectives of PT 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 of the cervicomandibular area. Therapeutic exercises for the masticatory and/or cervical spine muscles are used to improve strength, coordination, endurance, mobility, stability, motor control and endurance of the muscular system [29]. Therapeutic exercise has grown enormously in PT due to its benefits in chronic conditions [3,30-32]. 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 [3,30-32]. Besides its effects on function and health, therapeutic exercise is known to have some pain relieving effects [33,34]. Therapeutic exercise has been seen as the PT treatment with more evidence for treating painful chronic musculoskeletal conditions. Therefore, exercise therapy is warranted when managing musculoskeletal pain. With Temporomandibular Disorders, therapeutic exercise has also been found to have positive results in reducing symptoms of patients with TMD [3,4]. 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 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 PT area. Knowing that these cervical muscular impairments could be present in subjects with TMD, will enable clinicians to focus on these impairments (i.e. endurance and performance of cervical muscles) and plan a more effective treatment instead of applying a general treatment without targeting specific impairments. This could open a new area of research since research investigating the effectiveness of PT programs targeting these impairments needs to be performed.

The specific clinical contributions of this project to PT obtained from each of the areas investigated in this project will be outlined below:

Association between jaw disability and neck disability

This project found that a strong relationship between the presence of neck disability and jaw disability due to TMD was present. This result supports the clinical findings regarding the relationship between CSD and TMD [35,36]. Subjects having greater disability in the jaw were more likely to have greater disability of the neck and vice versa, although, because of the nature of this study, a cause and effect relationship could not be established.

These findings have clinical implications since clinicians need to be aware that not only signs and symptoms between the neck and jaw regions should be considered. The level of disability or the impact of the condition 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]) should also be looked at. 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, PT treatment needs to focus on both areas since the improvement of one could have an influence on the other. These results are in agreement with the results obtained by Wiesinger et al. [37], regarding TMD and spinal pain. They indicate a strong co-morbidity between these two conditions, suggesting that they may share risk factors or that they may influence each other. They found that the prevalence of fatigue/stiffness, pain, impaired jaw opening, and headaches, as well as the overall prevalence of any TMD symptoms and severe TMD symptoms increased in a dose-response pattern in relation to frequency/severity of spinal pain (i.e. neck, shoulder or back pain) and vice versa [37]. 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 and spinal complex.

The results of this study also indicated that the way one assesses and treats TMD should be reconsidered. This has generated a shift away from evaluation of only signs and symptoms toward the impact that signs and symptoms have on the function of individuals with pain [38,39]. The International Classification of Functioning, Disability and Health (ICF) from the World Health Organization (WHO) was 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 [40]. Thus, the use of the ICF framework as well as the use of outcomes that evaluate not only body structures or functions but also the impact of these impairments on subjects' activity and participation need to be considered for use in this group of subjects. According to Ohrbach [40], "integrating the information from limitation and disability into a clinical assessment model and treatment facilitates the process of evaluation and treatment implementation for patients with TMD", by focusing on all aspects of disability (i.e. body structures, body function, activities and participation), all aspects of a clinical complaint can be understood [41,42]. In addition, this research highlights the use of well validated outcome measures by clinicians and researchers working in this area, that address different aspects of disability.

Head and cervical posture and TMD

In this research, it was found that subjects with TMD had neither statistically significant nor clinically relevant 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 years. Physical therapists have commonly used cervical-head posture re-education techniques in order to address postural abnormalities in patients with neck involvement [43]. 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 [44]. The results of the present study along with a current systematic review [6], found that 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) was not significantly altered in patients with TMD, 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. [45], 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 could also explain more accurately the symptomatology in these patients. 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. This will open an extended and new area of research.

According to O'Leary et al. [43], postural evaluation and treatment should be 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 should consider these recommendations when treating these subjects in clinical practice.

Cervical muscle dysfunction and TMD: models and findings

The study of the cervical muscle dysfunction in subjects with TMD has not been performed previously 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 and thus many models have been generated [27,46-55]. The "pain adaptation model" [56] explains the interaction between muscle pain and motor control. According to this model, 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 [57] has suggested the "neuromuscular pain activation model". This model proposed that the 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 occurs during functional activities in the presence of pain [57]. Generally, the inhibition occurs more frequently in deep spinal muscles which control joint stability [57]. Recently, Murray and Peck [58] proposed a new model to explain motor changes in presence of pain called "the integrated pain adaptation model". This model proposed that complex changes occurred in the whole sensorimotor system in the 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 acting as an agonist or antagonist. In addition, this model highlighted that motor responses to pain could be different between individuals. Supporting this idea, Hodges et al. [59], also reported that no two subjects showed identical patterns of increased activity of the low back muscles when they underwent experimental pain. They felt that [59] these motor changes occurred in an attempt to maintain homeostasis and to minimize further pain. However, it is possible that these motor adaptations to pain could lead to further pain, injury, and disability. Thus, these models could explain the behavior of the cervical muscles in the presence of pain. There is supporting evidence that changes in muscle behaviour and function such as reduced activation of the deep cervical muscles, augmented superficial activity of the sternocleidomastoid (SCMs) and anterior scalene (SAs) muscles, changes in feedforward activation, reduced capacity to relax of 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 [27,46-49,53,54,60]. Furthermore, it has been shown, through the use of magnetic resonance imaging (MRI), that subjects with pain presented with an altered physical structure of the cervical muscles [61-63]. These changes included widespread atrophy, pseudo hypertrophy, and fatty replacement of cervical extensor muscles in patients with neck pain. Changes have been 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 [61-63]. Fiber type changes also have been observed in cervical flexor and extensor muscles in patients with cervical pain [64]. All of these changes at the muscular level could be related to 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 the present project are in line with the results obtained by this new research. Subjects with TMD, especially subjects with mixed TMD, were found to have increased activity in the superficial cervical muscles, when compared with healthy subjects while performing the CCFT. 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 [65]. These results show a potential change in the motor strategy of the cervical muscles in subjects with TMD to control the cervical spine when compared with healthy subjects. This increased activity in the superficial muscles could be seen as a strategy to compensate for the dysfunction of the deep flexor muscles. The response observed in the present study is in line with the integrated pain adaptation model theory [58]. 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 [66]. 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 [57]. Therefore, it is possible that decreased muscle activation caused by pain could have the potential to affect joint stability in patients with neck involvement [67-74]. As stated by Herzog et al. [66], "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 of the controlling muscles and also with changes in the pattern of muscle contraction associated with a joint [75-77]. 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 fatigue 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 isometric 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 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 the 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 during daily activities. 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 [78-80], pain from any of the upper three cervical synovial joints and muscles innervated by the upper cervical spinal nerves could be perceived in any 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 [81-88]. 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 it 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 [89]. If the 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 as seen in patients with TMD.

Given the clinically relevant results found in this study, the information described above is important to clinicians working in this area. It highlights that some important components of proper muscle performance such as the endurance capacity of the cervical flexor 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 the 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 and treat these impairments sooner to decrease the vulnerability of the cervical spine, thus contributing to improving the functioning of the craniocervical system in subjects with TMD and subsequently reduce the painful inputs to the trigeminocervical nucleus.

Cervical muscle training as possible physical therapy treatment for TMD

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 [45,90,91]. 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 focused 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 [90-93]. Deep flexor training in patients with cervicogenic headache (CEH) has been shown to decrease pain and the frequency of headaches [91]. The same findings were corroborated by van Ettekoven and Lucas [94] in a sample of subjects with tension-type headache using craniocervical (deep flexor) 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 [95]. Furthermore, an endurance program targeting the cervical flexor muscles found that subjects who underwent this type of training, improved cervical flexor strength and showed reduced myoelectric manifestations of fatigue of the cervical flexor muscles, along with a decrease in pain and disability of the neck [90]. The same effects were found when training the endurance of the cervical extensor muscles in a group of patients with neck pain and cervical disk disease after anterior cervical decompression and fusion [96]. According to Falla et al. [90], the improvements in strength and endurance capacities after treatment could be responsible for the reported efficacy of this type of exercise program in musculoskeletal pain conditions. They reported that a craniocervical exercise program decreased pain intensity and improved function of the neck [90]. The effects of this program were attributed to an increase in stabilization, 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 [97]. Furthermore, preliminary evidence has found that exercises addressing these types of impairment (i.e. training of neck flexor muscles) as part of cervical spine treatment in people with TMD, reduced pain and improved function (i.e. increasing pain-free mouth opening), which potentially supports the fact that patients with TMD could benefit from treatment to impaired cervical flexor muscles [98]. Thus, these results testing the effectiveness of exercise 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 since up to now this type of training has not been proven in a large clinical trial.

It has also been shown that exercises addressing the neck extensor muscles increased the total neck cross sectional area (CSA) by about 13%. The hypertrophy obtained after12 weeks of training was mainly due to increases in CSA for the splenius capitis (24%), semispinalis capitis (24%), semispinalis cervicis and multifidus muscles (24.9%) [99]. Training of the cervical muscles was demonstrated by an increased CSA of the SCM and trapezius muscles as well as decreased fatigability of the cervical muscles after 8 weeks of training [100]. 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 cervical pain. Therefore, there is evidence that treating these impairments found in patients with TMD, through specific and well designed exercises targeting the cervical muscles can obtain positive effects for stabilization of the cervical system and avoid further injury decreasing the painful input into the trigeminiocervical nucleus. Thus, the results of these studies provide a major contribution to the area of PT and exercise prescription for patients with TMD. Knowing that these cervical muscular impairments could be present in subjects with TMD, will enable clinicians to focus on these impairments (i.e. endurance and performance of cervical muscles) and plan a more effective treatment instead of applying a general treatment without targeting specific impairments. This could open a new area of research since research investigating the effectiveness of PT programs targeting these impairments needs to be performed.

Limitations of this research project

The limitations of this research were as follows:

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 taken into consideration when attempting to extrapolate these results.

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.

Subjects participating in this research study presented with moderate 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 observed by others [63].

Future research

This study is a starting point to increase the scientific rigor of the research especially as it applies to PT in the assessment and treatment of TMD. Some directions for future investigations could be:

1. To study cervical joint dysfunction assessment and treatment and its relationship with craniofacial pain. The present 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 investigate 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 [40]. The present 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 could influence the adaptive capacity of subjects to pain.
3. To investigate the use of dynamic posture evaluation in painful musculoskeletal conditions such as TMD. As pointed by Kraus [101], 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 their symptomatology.
4. To evaluate whether posture assessment using surface measures in photographs is a valid method of assessing head and cervical posture [102].
5. To evaluate fatigue of the cervical flexor muscles and other muscles of the craniocervical system in this population using electromyoraphy to determine whether reduced endurance is present in specific cervical muscles with a more objective tool. The present study evaluated the endurance of the cervical flexor muscles using only a clinical test.
6. To develop a databank with normative values of maximal isometric cervical flexor muscle strength and endurance holding times at different levels of MVC in a large representative sample of healthy subjects. Quantitative measures of cervical muscles strength and endurance presented with a large amount of variablity among subjects in different studies. This variability could be attributed to different protocols used, samples tested, and different anthropomorphic characteristics of the subjects such as age, muscle length and mass, and weight of the head [103]. Thus, with this variability in mind, it is presently 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 [46].
8. To explore the evaluation of maximum strength in other cervical muscle groups such as the extensors, rotators and lateral inclinators 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 in subjects with TMD using magnetic resonance imaging or ultrasound evaluation to help to understand functional changes in cervical muscles seen in this population. While the present project found alterations in muscle functioning in subjects with TMD, it is still unknown whether structural changes in cervical muscles are present in subjects with TMD as shown by other studies in subjects with WAD and neck pain conditions [61-63,104].
10. To implement a randomized controlled trial (RCT) that addresses impaired endurance and performance capacities of the cervical muscles through cervical exercises in patients with TMD and test whether these exercises decrease pain, improve function, and quality of life in patients with TMD.

CONCLUSIONS

Based on the results obtained from this research, a strong relationship between neck disability and jaw disability was found. Subjects with Temporomandibular Disorders presented with abnormal pattern of contraction of the cervical flexor muscles and an increased fatigability of the flexor and extensor cervical muscles when compared with healthy subjects. Differences in craniocervical posture as well as maximum cervical flexor muscle strength were considered not clinically relevant. The results of the analyzed studies provided an important clinical contribution to the area of Temporomandibular Disorders and physical therapy. It identified impairments in the cervical spine in patients with Temporomandibular Disorders that could help guide clinicians in the assessment and prescription of more effective interventions for individuals with Temporomandibular Disorders. A randomized controlled trial that addresses impaired endurance and performance capacities of the cervical muscles through cervical exercises in patients with Temporomandibular Disorders and test whether these exercises decrease pain, improve function, and quality of life in patients with Temporomandibular Disorders is urgently needed.

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