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Original article

Cervical flexion-rotation test and physiological range of motion – A comparative study of patients with myogenic temporomandibular disorder versus healthy subjects

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ABSTRACT

Background: Temporomandibular Disorders (TMD) refer to several common clinical disorders which involve the masticatory muscles, the temporomandibular joint (TMJ) and the adjacent structures. Although neck signs and symptoms are found with higher prevalence in TMD patients compared to the overall population, whether limitation of cervical mobility is an additional positive finding in this cohort is still an open question.
Objective: To compare the physiological cervical range of motion (CROM) and the extent of rotation during cervical flexion (flexion-rotation test, FRT) in people with TMD (muscular origin) and healthy control subjects.
Method: The range of motion of the neck and FRT was measured in 20 women with myogenic TMD and 20 age matched healthy controls.
Results: Women with myogenic TMD had significantly lower FRT scores compared to their matched healthy women. No difference was found between groups in CROM in any of the planes of movement. The FRT was positive (less than 32°) in 90% of the TMD participants versus 5% in the healthy control but the findings were not correlated with TMD severity.
Conclusion: The results point out a potential involvement of the upper cervical joints (c1-c2) in women with myogenic TMD

1. Introduction

Temporomandibular Disorders (TMD) relate to a group of conditions that may result in pain and dysfunction in the masticatory muscles, the temporomandibular joint and their associated structures (De-Wijer et al., 2010). TMD are very common among the general population and are considered as the main cause of chronic orofacial pain (Drangsholt et al., 1999). Epidemiological studies indicate that the majority of people with TMD (PWTMD) are young women aged 20–40 (Manfredini et al., 2011). TMD are characterized with clinical signs and symptoms, mainly pain but also clicks during jaw functions such as chewing, speaking and yawning (Okeson, 1996). Among the TMD the most common disorder is caused by pain from the masticatory muscles – the myogenic TMD (Manfredini et al., 2011). In addition to their facial symptoms PWTMD commonly suffer from signs and symptoms in their head and neck such as headaches, ear pain, and cervical spine disorders (De –Wijer et al., 1996; De Laat et al., 1998; Visscher et al., 2001; Stiech-Scholtz and Tschernitschek, 2003).

The TMJ and the upper cervical spine motion segments (OCC-C1-C2) are anatomically proximal. Functionally, jaw opening tends to involve atlanto-occipital extension while jaw closing involves the opposite cranial movement (Eriksson et al., 2000). It has been shown that a postural change of the cervical spine has led to a postural change of the jaw and vice versa (Zafar et al., 2000; Moya et al., 1994). According to the “Sliding Cranium theory” (Makofsky, 1989) the commonly demonstrated “forward head posture” creates biomechanical compressive forces in the TMJ due to loads on the

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suprahyoid muscles. However, this theory is not well supported scientifically (Olivo et al., 2006).

However, there is some evidence that pain and sensory input from the tissues of the neck may project pain to the head, including the masticatory muscle area (Simons, 1999). The neuroanatomical basis for pain projection from the neck to the face is explained by the trigemino-cervical nucleus that receives nociceptive inputs from the upper cervical spine and the fifth cranial nerve, the trigeminal (Marfurt and Rajchert, 1991). It has been shown that noxious stimuli of the trigeminal nerve create pain sensation in the cervical area and vice versa (Bartsch and Goadsby, 2003). In addition, injection of inflammatory factors to the cervical muscles may lead to an uncontrolled recruitment of the masticatory muscles (Hu et al., 1993). This theory is known as the "convergence theory" (Marfurt and Rajchert, 1991).

Some studies support the connection between postural changes and TMD (Olivo et al., 2006). This connection is related mainly to the forward head posture (FHP) (Lee et al., 1995). In addition to that some short term clinical improvement in PWTMD has been shown after a postural correction of the neck (Wright et al., 2000), but this finding has not been supported by other studies (Hackney et al., 1993; Visscher et al., 2002; Armijo Olivo et al., 2006).

Compared to the general population PWTMD report cervical symptoms with a higher prevalence (Ciancaglini et al., 1999) and there is some correlation between the severity of their TMD and the subjective neck functional limitation (Armijo-Olivo et al., 2010a). Clinically it has been shown that PWTMD have higher sensitivity to cervical structures palpation (De –Wijer et al., 1996; Visscher et al., 2001; Stiech-Scholtz and Tschernitschek, 2003), limited cervical range of motion (De –Wijer et al., 1996; Stiech-Scholtz and Tschernitschek, 2003), and limitation in cervical segmental motion (Stiech-Scholtz and Tschernitschek, 2003). However, none of the studies applied measurement tools that provided sufficiently reproducible or valid outcome measures scores (De –Wijer et al., 1996; Stiech-Scholtz and Tschernitschek, 2003). Recently cervical muscular performance was assessed in PWTMD. Their findings demonstrated an endurance limitation of the deep cervical flexors and cervical extensors compared to healthy controls (Armijo-Olivo et al., 2010b, 2012). Although there is some evidence to support a clinical connection between cervical spine dysfunction and TMD, there is a clear lack of clinical studies that support etiological connections. We are aware of only one recent study that has demonstrated an improvement of cervical clinical parameters in patients with TMD after physiotherapeutic intervention that was directed to the temporomandibular area only (Piekartz and Hall, 2013). However, the diagnostic criteria for TMD used in that study were not clear.

The 3-D mobility of the cervical spine is one of the most important clinical and empirical measures used for functional evaluation of the neck (Johnston et al., 2008; Zwart, 1997; Sjaastad et al., 1998; De-Koning et al., 2008b; Williams et al., 2010; Hall and Robinson, 2004). A specific, widely documented, manual test that assesses the rotatory motion of the atlanto-axial joints (C1-C2) is the cervical Flexion-Rotation Test – FRT (Hall and Robinson, 2004; Hall et al., 2008, 2010a; Mark et al., 2007; Takasaki et al., 2011; Hall et al., 2010b). In this passive manual test, the rotatory movement of the cervical spine is measured in supine position while the cervical spine is also in maximal physiological flexion (Hall and Robinson, 2004). This combination of physiological movements leads to a relatively isolated rotation in the atlanto-axial motion segment (Hall et al., 2008) while the test has been shown to possess high sensitivity and reproducibility in the diagnosis of cervicogenic headache (Hall and Robinson, 2004; Hall et al., 2008, 2010a; Mark et al., 2007; Takasaki et al., 2011; Hall et al., 2010b). To the best of our knowledge, the only study to-date that has assessed FRT in patients with TMD vs. controls indicated significant reduction in cervical mobility among PWTMD (Grondin et al., 2015). All range of motion measurements in this study, including the FRT, were tested only once and therefore the reliability of their results is questionable.

Hence the objective of the present study was to compare the 3-plane pure active physiological cervical movements (in upright position, repeated 3 times) and FRT (repeated 3 times) in PWTMD (muscular origin) and healthy controls. We hypothesized that a difference existed between the two cohorts, more meaningful in the FRT than in pure physiological cervical ROM, and that the severity of the TMD was correlated with cervical mobility, especially as seen in the FRT.

We hypothesized that there is a difference and it will be more significant in the FRT than in pure physiological cervical range of motion. We also hypothesized that there is a correlation between the severity of the TMD and of the cervical mobility (especially in the FRT).

2. Method

2.1. Participants

The study consisted of 40 women, 20 in the TMD group and 20 age matched controls. The average age of the TMD group was 33.0 ± 9.2 and 33.3 ± 8.55 for the TMD and control group, respectively. The participants with myogenic TMD were recruited from patients attending the Orofacial Pain and TMD (OPTMD) clinic whereas their healthy counterparts were recruited from the staff and students of Tel Aviv University's Schools of Dental Medicine and Health Professions. All participants signed an informed consent form. Approval for the study was obtained from the Ethics Committee (Human Subjects) at Tel Aviv University.

2.2. Myogenic TMD group

The inclusion criteria for this group included:

a) Age eighteen to 50 years.
b) Pain in the masticatory muscles/TMJ area for the last 3 months.
c) A diagnosis of myogenic TMD by a dentist specializing in TMD dysfunction, according to the research diagnostic criteria for TMD – RDC/TMD (University of Washington) where the 2 main factor for a positive diagnosis subjective complaint of pain in the masticatory muscle, around the eyes and ears at rest or during masticatory functions and reproduction of pain during palpation in at least 3 of 20 facial anatomical sites. Patients diagnosed with disc derangement TMD together with myogenic TMD were allowed to participate.

The exclusion criteria for the TMD group consisted of:

a) Significant neck pain that made the patient seek medical help, painful dental/periodontal disease, systemic or neurological disease, and/or psychiatric disease that may affect cooperation and reliability
b) Diagnosis of other painful TMD, without myogenic TMD.
c) Primary cervical spine disorder such as disc herniation or significant spinal degenerative changes.
d) Systemic disease that is likely to affect the mobility of the cervical spine such as ankylosing spondylitis.

Prospective participants in the control group had to be:
18-50y of age; without any functional disorder of the masticatory system or complains for the last year that could indicate such

disorder; without organic cervical disorder or significant neck pain for the last 6 months and without systemic diseases that could affect the cervical spine range of motion (such as ankylosing spondylitis).

2.3. Selection procedure of the TMD group

Patients who visited the OPTMD clinic and were diagnosed by one of the clinical staff (dentists with specific training of masticatory system disorders and orofacial pain) with myogenic TMD were referred to the first author, a physical therapist with advanced training in manual therapy of the cervical spine. The TMD diagnosis was based on the RDC/TMD following a detailed subjective and objective clinical assessment. This is a routine assessment that all the patients in this clinic undergo to establish the diagnosis and the treatment plan. Patients who were deemed suitable for the study were instructed about the study and its objectives and about the planned cervical assessment. Only those participants who have signed the informed consent forms had gone through the cervical spine assessment.

2.4. Outcome measures

All participants were tested using the FRT (Hall and Robinson, 2004; Hall et al., 2008, 2010a; Mark et al., 2007; Takasaki et al., 2011; Hall et al., 2010b) and the active cervical ROM. The FRT is used primarily for assessing the mobility of the atlanto-axial motion segment (C1-C2). The normal ROM for this test is about 44° of rotation to each side (Hall et al., 2010a). A positive test for motion limitation in the C1-C2 segments has been described as less or equal to 32° to one of the sides (Hall et al., 2008, 2010a; Mark et al., 2007; Takasaki et al., 2011; Hall et al., 2010b). This test has been associated with a high sensitivity for the diagnosis of cervicogenic headache and diagnostic accuracy with fairly high intra- and inter-reliability based on either expert or novice physiotherapist-assessor (Hall and Robinson, 2004; Hall et al., 2008, 2010a; Mark et al., 2007; Takasaki et al., 2011). The FRT has also been shown to possess a high validity regarding hypo-mobility of the atlanto-axial motion segment (Hall et al., 2008, 2010b; Mark et al., 2007).

2.5. Measurement of cervical RoM

Both the maximal RoM and FRT were assessed using the CROM device (Performance Attainment Associates. 958 Lydia Drive, Roseville, Minnesota, USA, 55113), a widely used instrument for neck motion studies (De-Koning et al., 2008b; Williams et al., 2010). The CROM utilizes 2 inclinometers attached to a plastic frame (the 'crown') for measuring sagittal and coronal plane motion. A compass is used for recording rotations (transverse plane).

2.6. Measurement procedure for the FRT

The CROM device was firmly attached to the head of the participant who lay supine on a treatment couch. The participant was asked to relax while her neck was moved to end of range cervical flexion by the examiner. In this flexed position the head and neck were passively rotated as far as possible within comfortable limits of pain or physiological stiffness (Illustrations A&B). The range was recorded and repeated 2 more times to both sides with 30s rest in between the tests. The finding was considered positive when the range of motion was smaller than 32° to at least one of the sides. The average of the 3 tests to each side represented the final score.

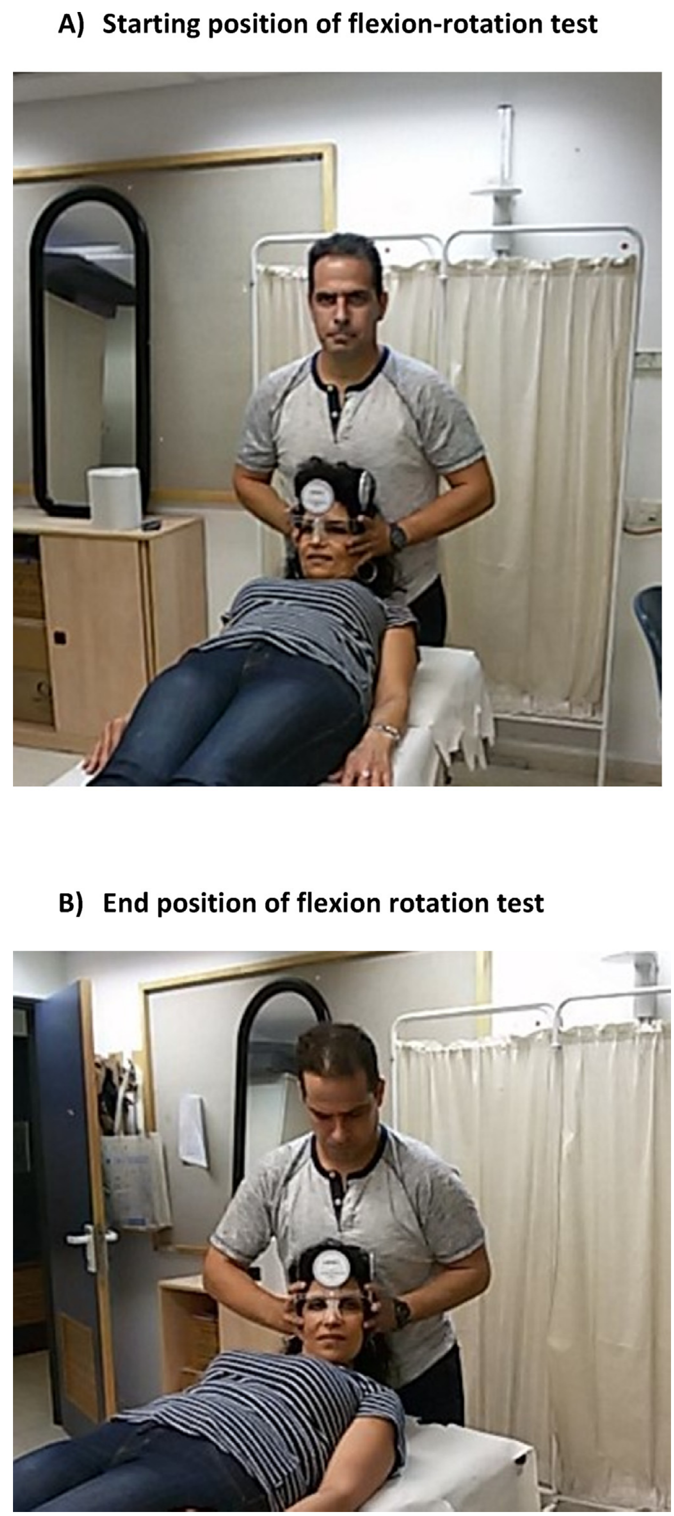

Fig. 1. Illustrations: The Cervical Range of Motion device and the Flexion Rotation Test: A) Starting position of flexion-rotation test. B) End position of flexion rotation test.

2.7. Measurement procedure for cervical range of motion

The test was performed in sitting with the trunk touching the back of the chair while the feet rested on the floor. The participant was also instructed to relax her shoulders and place her arms comfortably besides her body. The CROM device was placed on the head and properly fixed by the examiner. The participant was then instructed to perform 6 physiological cervical movements in this sequence: flexion, extension, right/left lateral flexion, right/left rotation. The result (in degrees) of each movement was recorded by the examiner and this procedure was then twice repeated with a 30s rest between consecutive movements. The average of the 3 measurements represented the final score for each individual movement.

2.8. TMD measurements

Maximal Unassisted Mouth opening (MUO) was measured (in mm) by the dental specialist. Current pain levels were measured using the Visual Analog Scale as part of the subjective RDC-TMD examination. Composite pain index was calculated as the average of current pain, worse and average pain levels in the past 6 months.

3. Statistical analysis

The analysis was carried out using SPSS (SPSS Inc., Chicago), version 21. The T test was used to compare the cervical physiological movements and FRT between the groups. In order not to exceed an overall type I error of 0·05, in case of multiple tests, the Bonferroni correction was used. The Fisher exact test was used to compare the proportions of participants with positive FRT (≤32°), while Pearson's r was used to correlate the cervical ROM (including FRT) with TMD parameters (pain levels and mouth opening). Finally, the Mann-Whitney test was used for the inter-group comparison of the coefficient of variation (CV) relating to each of the cervical movements (including the FRT). The CV represents the consistency in performing repeated movements of the head and is defined as the ratio of the standard deviation σ to the mean μ.

Table 1
Temporomandibular Disorders group description.

Number of subjects in group	20
Average age	33
MFP[a] without limited mouth opening	9
MFP[a] with limited mouth opening	2
MFP[a] without limited mouth opening + Disc disorder	6
MFP[a] with limited mouth opening + Disc disorder	3
Combined MFP[a] & Disc disorder	9
Subjects with unilateral jaw pain	16
Subjects with bilateral pain	4

[a] MFP – Myofascial Pain.

4. Results

Since there was not enough power to conduct an analysis among patients suffering from pure myogenic TMD (n = 11, Table 1) it was decided to analyzed those patients together with the patients suffering from combined myogenic TMD and internal derangement (n = 9, Table 1).

4.1. Cervical Flexion-Rotation test (FRT) and active ROM

Significant differences between groups were found for all FRT parameters (Table 2): FRT to the right (P<0.01), left (P<0.01) and right + left (P<0.01). The TMD group was limited compared to the control group in all parameters. No difference was found between groups for the 6 pure physiological cervical active movements (flexion, extension, right and left lateral flexion and right and left rotation).

4.2. Proportions of positive FRT

FRT was positive (≥32°) towards at least one side, in 18 out of 20 subjects (90%) of the TMD group whereas only a single subject scored positive in the control group.

4.3. Coefficient of variation (CV)

The CV scores of all cervical movements (including FRT) of the TMD group were consistently higher than those of the control

Table 2
Neck movement: a comparison between a Temporomandibular Disorders Group and a Healthy Group.

	Group	N	Mean	Std. Dev	P value (Bonferroni)
Flexion	[a]TMD	20	60.50	10.78	4.9664
	Healthy	20	58.75	11.39	
	Differences between groups (95%Confidence interval)		1.75 (−5.9, 9.4)	16.36	
Extension	[a]TMD	20	66.25	15.39	1.4946
	Healthy	20	72.41	13.55	
	Differences between groups (95%Confidence interval)		6.16 (−3.3, 15.6)	20.36	
Right Lateral Flexion	[a]TMD	20	41.75	9.27	4.5038
	Healthy	20	43.25	6.78	
	Differences between groups (95%Confidence interval)		1.5 (−3.77, 6.77)	11.27	
Left Lateral Flexion	[a]TMD	20	42.91	9.95	5.6350
	Healthy	20	44.00	7.84	
	Differences between groups (95%Confidence interval)		1.08 (−3.85, 6.02)	10.55	
Right Rotation	[a]TMD	20	70.50	7.66	5.1460
	Healthy	20	71.66	8.12	
	Differences between groups (95%Confidence interval)		1.16 (−3.51, 5.84)	10.0	
Left Rotation	[a]TMD	20	68.08	9.60	0.5613
	Healthy	20	73.83	9.91	
	Differences between groups (95%Confidence interval)		5.75 (0.33, 11.1)	11.56	
[b]FRT Right	[a]TMD	20	27.16	7.93	0.000 [c]
	Healthy	20	40.83	5.63	
	Differences between groups (95%Confidence interval)		13.66 (10.2, 17.0)	7.28	
[b]FRT Left	[a]TMD	20	29.91	9.72	0.000 [c]
	Healthy	20	41.41	4.43	
	Differences between groups (95%Confidence interval)		11.5 (6.4, 16.6)	10.89	

[a] TMD – Temporomandibular Disorders.
[b] FRT – Cervical Flexion-Rotation Test.
[c] Significance.

group. However, the differences reached significance only for the right and left FRT, left lateral flexion and left rotation (Table 3).

4.4. Correlations between TMD and cervical spine parameters

The correlations between TMD parameters (present pain, average pain, worse pain for the last 6 months and mouth opening range) and specific neck movement including FRT were negligible (Table 4).

5. Discussion

The main findings of this study relate to a significant limitation in the FRT in PWTMD compared to matched healthy subjects, coupled with a very high proportion of positive FRT (90%) in the former group. This upper neck mobility limitation is very similar in its intensity to that reported by Grondin et al. (2015) and provides support to the notion of upper cervical spine hypo-mobility in PWTMD). This study adds strength and reliability as the FRT was repeated 3 times for each participant and was performed by a senior clinician. Additionally, the upper neck mobility limitation and the high proportion of positive FRT are also similar to those of people presenting with cervicogenic headache (Hall and Robinson, 2004; Hall et al., 2008, 2010a; Mark et al., 2007). These similarities point out to a possible cervical dysfunction in myogenic TMD (Hall and Robinson, 2004; Hall et al., 2008, 2010a; Mark et al., 2007) while suggesting a co-morbidity of CGH and myogenic TMD and/or etiological factor of upper cervical spine dysfunction and myogenic TMD. Prior to the commencement of the study, there was no established evidence regarding the possibility of a coexistence of CGH with TMD patients. Therefore, we chose not to include such test. In view of the current results, future studies conducted by our group will include a clinical diagnosis of CGH in this cohort of patients.

In contrast to Grondin et al. (2015), there was no difference between the groups in any of the pure active physiological movements. However, as pointed before the reliability of the findings reported by Grondin et al. is questionable. Interestingly, the relatively normal active physiological cervical movements versus the impaired FRT resemble the finding of a previous study that focused on cervical ROM and FRT in patients with CGH (Hall and Robinson, 2004). Thus the selective role of FRT in differentiating the mobility of the upper and the lower cervical spine segments is underlined. Significantly, without applying the FRT, it could have been wrongly argued that the mobility of the cervical spine was similar in subjects with myogenic TMD and in the uninvolved subjects. The

Table 3
The Coefficient of Variance (in %) for the various cervical movements in the Temporomandibular Disorders and control groups.

	Group	Mean	Std. Deviation	Std. Error Mean	P value
[a]CV of Flexion	[b]TMD	7.86	4.83	1.08	0.192
	Healthy	6.03	3.88	0.86	
[a]CV of Extension	[b]TMD	5.10	4.12	0.92	0.414
	Healthy	4.09	3.99	0.89	
[a]CV of right Rotation	[b]TMD	5.04	4.51	1.01	0.086
	Healthy	2.49	2.46	0.55	
[a]CV of right lateral Flexion	[b]TMD	6.84	4.88	1.09	0.076
	Healthy	4.03	3.91	0.87	
[a]CV of left lateral Flexion	[b]TMD	7.31[a]	4.78	1.07	0.023[c]
	Healthy	4.35	3.89	0.87	
[a]CV of left Rotation	[b]TMD	5.89[a]	3.43	0.76	0.04[c]
	Healthy	3.90	2.72	0.60	
[a]CV of right FRT	[b]TMD	12.87[a]	6.28	1.40	0.000[c]
	Healthy	5.36	4.70	1.05	
[a]CV of left FRT	[b]TMD	8.23[a]	9.01	2.01	0.046[c]
	Healthy	2.66	3.35	0.75	

[a] CV – Coefficient of Variance.
[b] TMD – Temporomandibular Disorders.
[c] Significance.

Table 4
Correlations between Temporomandibular Disorders and cervical range of motion parameters.

Measurement	Statistical analysis	Maximal unassisted mouth opening	Current Pain	[a]Composite Pain Index
Flexion	P value	0.966	0.257	0.409
	Pearson correlation	0.01	−0.266	−0.195
Extension	P value	0.488	0.160	0.533
	Pearson correlation	−0.164	−0.327	−0.148
Right lateral flexion	P value	0.933	0.961	0.911
	Pearson correlation	−0.02	0.012	0.027
Left lateral flexion	P value	0.275	0.666	0.645
	Pearson correlation	−0.257	−0.103	0.11
Right rotation	P values	0.209	0.736	0.756
	Pearson correlation	0.293	0.08	−0.074
Left rotation	P values	0.662	0.635	0.447
	Pearson correlation	−0.04	0.113	0.180
[b]FRT right	P value	0.319	0.539	0.793
	Pearson correlation	0.235	0.146	0.063
[b]FRT left	P value	0.608	0.159	0.268
	Pearson correlation	−0.122	−0.327	−0.26

[a] Composite Pain Index - the average of current pain, worse and average pain levels in the past 6 months.
[b] FRT – Cervical Flexion-Rotation test.

differences between selective upper cervical spine movement and general cervical spine movements could be due to a compensatory ability of the lower cervical motion segments when motion in their upper counterparts was compromised. For example, in a patient who presents with a severe limitation in C1-C2 segmental rotation, the other cervical motion segments (C2-C7) may take over to the extent that no limitation in the general cervical rotation is apparent. In such a case the FRT is likely to be positive as this clinical test is sensitive to rotatory movement of the C1-C2 segment (Takasaki et al., 2011).

In spite of the significant difference in FRT scores between the two groups no correlation between the FRT limitation and any of the measured TMD pain and movement parameters was indicated. Previous studies referring to the correlation between FRT scores and severity of CGH yielded contradictory findings (Hall and Robinson, 2004; Mark et al., 2007; Hall et al., 2010b). The main explanation for this negative finding focuses on the subjective nature of pain experience (Hall et al., 2008). Pain may be viewed as an individual response to threat, real or perceived, not necessarily as sign of damage. (Butler). Therefore, moderate cervical stimuli may be interpreted as severe pain in one subject while a severe cervical stimulation may lead to a moderate pain in another. Similarly, no correlation was detected between the severity of the FRT restriction and limitation in opening of the mouth. The finding relating to no correlation between the facial dominant side of pain and the positive FRT side is in line with several CGH population studies (Hall et al., 2010a; Mark et al., 2007) and in variance with other (Hall and Robinson, 2004). Although noxious stimuli from upper cervical unilateral structures such as the facet joint is likely to refer pain to the same facial side one cannot exclude the possibility that such stimuli may affect the mobility of the motion segment to the contra-lateral side.

5.1. Strengths and limitations of the study

This is the second ever published study which assessed FRT in PWTMD and similar to the first study found evidence of upper cervical spine disorder in this population. The findings support the importance of considering involvement of the upper cervical spine in the assessment and management of PWTMD.

On the other hand, generalization of the results of this study is limited by the relatively low number of participants, women only and by the fact that some participants presented mixed TMD diagnosis. In other words, in order to get enough power 2 different subgroups (pure myogenic & myogenic + Disc disorder) were analyzed together. Additionally, the examiner was not blinded to diagnosis of participants, creating a potential bias.

6. Conclusions

A significant limitation in rotatory movement of the upper cervical was found among patients suffering from myogenic TMD and presenting with positive FRT (90%). On the other hand, pure cervical physiological movements in these patients did not differ from those recorded in uninvolved subjects. Furthermore, there was no correlation between TMD severity and any cervical range of motion, including FRT. Thus this study supports a clinical relationship between upper cervical spine disorder and myogenic TMD.

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