Do subjects with acute/subacute Temporomandibular Disorder have associated cervical impairments: A cross-sectional study

Harry von Piekartz[1], PhD; Ani Pudelko, BSc; Mira Danzeisen, BSc; Toby Hall[2], PhD; Nikolaus Ballenberger[1], PhD

[1]Professor of Physiotherapy, University of Applied Science. Osnabrück, Germany

[2]Adjunct Associate Professor, School of Physiotherapy and Exercise Science, Curtin University of Technology, Hayman Road, Bentley, Western Australia

Corresponding author:

Professor Harry von Piekartz

Physiotherapy Clinic for Manual Therapy and Applied Neurobiomechanic Science

Stobbenkamp 10,

7631 CP Ootmarsum

The Netherlands

Email: H.von-Piekartz@fh-osnabrueck.de

Telephone: Tel +49541969-3526

Abstract

BACKGROUND: There is preliminary evidence of cervical musculoskeletal impairment in some temporomandibular disorder (TMD) pain states.

OBJECTIVES: To determine whether people with TMD, classified as either mild or moderate/severe TMD, have more cervical signs of dysfunction than healthy subjects.

DESIGN: Cross-sectional survey

METHOD: Based on the Conti Amnestic Questionnaire and examination of the temporomandibular joint (Axis I classification of the Research Diagnostic Criteria for TMD), of 144 people examined 59 were classified to a mild TMD group, 40 to a moderate/severe TMD group and 45 to an asymptomatic control group without TMD. Subjects were evaluated for signs of cervical musculoskeletal impairment and disability including the Neck Disability Index, active cervical range of motion, the Flexion-Rotation Test, mechanical pain threshold of the upper trapezius and obliquus capitis inferior muscles, Cranio-Cervical Flexion test and passive accessory movements of the upper 3 cervical vertebrae.

RESULTS: According to cervical musculoskeletal dysfunction, the control group without TMD were consistently the least impaired and the group with moderate/severe TMD were the most impaired. These results suggest, that the more dysfunction and pain is identified in the temporomandibular region, the greater levels of dysfunction is observable on a number of cervical musculoskeletal function tests. The pattern of cervical musculoskeletal dysfunction is distinct to other cervical referred pain phenomenon such as cervicogenic headache.

CONCLUSION: These findings provide evidence that TMD in an acute/subacute pain state is strongly related with certain cervical spine musculoskeletal impairments which suggests the cervical spine should be examined in patients with TMD as a potential contributing factor.

Keywords: Temporomandibular disorder, neck disability, cervical spine, cervico-trigeminal complex

Introduction

Temporomandibular dysfunction (TMD) is defined as a structural and functional disorder with clinical signs and symptoms that affects the masticatory muscles and/ or the temporomandibular joint (TMJ) and associated structures (Svensson and Graven-Nielsen, 2001; Thilander et al., 2002). TMD has a one-year prevalence of 19% for frequent myofascial complaints, an incidence of 4%, and is more frequent in women (Thilander et al., 2002). Although common, TMD does not always cause symptoms. For example, one survey found that 50% of a sample of 4289 adults had at least one TMD sign, but only 10% reported symptoms in the temporomandibular region (Gesch et al., 2004). Many contributing factors contribute to the development and enhancement of signs and symptoms of TMD (Bogduk, 2001; Armijo-Olivo and Magee, 2012) and may influence pain, pain behavior and orofacial function (LeResche, 1997; Tuncer et al., 2013).

One factor influencing TMD might be the cervical spine. It has been reported, that people with TMD associated pain have significantly more pain in the cervical spine than those without (de Wijer et al. 2006, Visscher et al., 2001). Confirmatory evidence of the association between the cervical and temporomandibular region is growing, possibly explained by the close anatomical connections as well as neurophysiological mechanisms linking the two regions (Armijo-Olivo and Magee, 2012; Ballenberger et al., 2012). This is expressed in associations between signs and symptoms of cervical dysfunction and TMD (de Wijer et al. 2006, Armijo-Olivo et al., 2006; von Piekartz and Hall, 2013).

Clinical studies demonstrate the influence of various head and neck postures on the movement of the TMJ as well as on mechanosensitivity and activity of masticatory muscles (La Touche et al., 2011; Ballenberger et al., 2012). Furthermore, a positive correlation ($r=0.82$; $p<0.05$) has been reported (Olivo et al., 2010) between scores on the neck disability index (NDI) and the jaw functional scale (JFS). One explanation for this is that jaw disability driven by TMD is accompanied by neck disability due to referred pain and/or altered motor control from the orofacial region (Olivo et al., 2010). Hence, TMD arises before cervical dysfunction which is influenced by the severity of TMD (Bevilaqua-Grossi et al., 2007). This association between the two regions is also demonstrated by the effect that treatment in one area has on the other (von Piekartz and Lüdtke, 2011). Piekartz and Hall (2013) reported positive effects of orofacial manual therapy on cervical movement impairment in patients with cervicogenic headache, which supports the theory of the pathophysiological relationship.

There is a close neurophysiological interaction between the orofacial and cervical regions through the trigeminocervical nucleus (Armijo-Olivo and Magee, 2012). Pain arising from joints and muscles, which are innervated by the upper cervical spinal nerves, can be perceived in other regions supplied by the trigeminal nerve (Bogduk, 2001). Hence, the question arises about the presence of cervical dysfunction in patients with TMD, particularly

with respect to the upper cervical spine. Although a number of studies have examined TMD and its connection to the cervical spine, the association between individual cervical measurements of musculoskeletal dysfunction and the severity of TMD has not been investigated. The objective of this present study was to examine whether subjects with TMD show more signs of cervical musculoskeletal dysfunction than healthy subjects and to investigate the association between severity of TMD and signs and symptoms in the cervical spine.

Methods

Subjects

Subjects with and without head and face pain were recruited over a period of 5-months through information flyers sent to 15 physiotherapy practices (four specialized in the management of head-face and neck pain) in Osnabrück and Hamburg, Germany. Volunteers were screened and classified by an independent examiner, familiar with the Research Diagnostic Criteria for Temporomandibular Dysfunction (RDC/TMD) Classification. Subjects were excluded if they were under 18 years old, had any history of fractures and/or surgery in the neck and/or jaw region, showed neurological deficits, suffered night pain or other inflammatory symptoms, were undergoing orthodontic treatment or were rated 3 or 4 on the Graded Chronic Pain Status (GCPS) questionnaire (criteria sufficient for classification to Axis ll). The GCPS is a valid measuring tool which has been used to classify the chronic pain state in TMD disorders (Bevilaqua-Grossi et al 2006) The questionnaire consists of seven questions: four are pain-related limitations and three items refer to pain intensity. The outcomes are classified into four subgroups, with grades I and II seen as a slight limitation (functional chronic pain) and grades III and IV as strong limitations (dysfunctional chronic pain) (von Korf et al 1992).

In order to detect a medium effect between three groups with 80% power and 5% type I error probability we aimed to recruit 159 individuals. Following initial screening, subjects were informed about the procedure and provided written informed consent before examination. Of 175 people volunteering (Figure 1), 144 were allocated following screening and were divided into three subgroups according to Conti Amnestic Questionnaire (CAQ) which comprises 10 questions that are related to problems originating from the temporomandibular region. Each question has three ranking options (0=none: 1=present: and 3=strong or bilateral). Subjects were categorized into one of four groups according to their total questionnaire score, with consequent likelihood of TMD as follows: 4- 9, none: 9-14, minimal: 15-21, moderate: 21-23,

strong (Conti et al 1996). The CAQ score has been shown to have a strong statistical association with the score from the modified Helkimo's Clinical Dysfunction index at a 95% level of confidence (Bevilaqua-Grossi et al 2006). In totally 31 volunteers were excluded because they did not fulfill the inclusion criteria. According to the combined CAQ score 45 volunteers were classified to the "NO TMD", 59 to the "mild TMD" and 40 to the "moderate/severe TMD" groups. Classification to a single "severe" group was not possible, as this group comprised only 7 people.

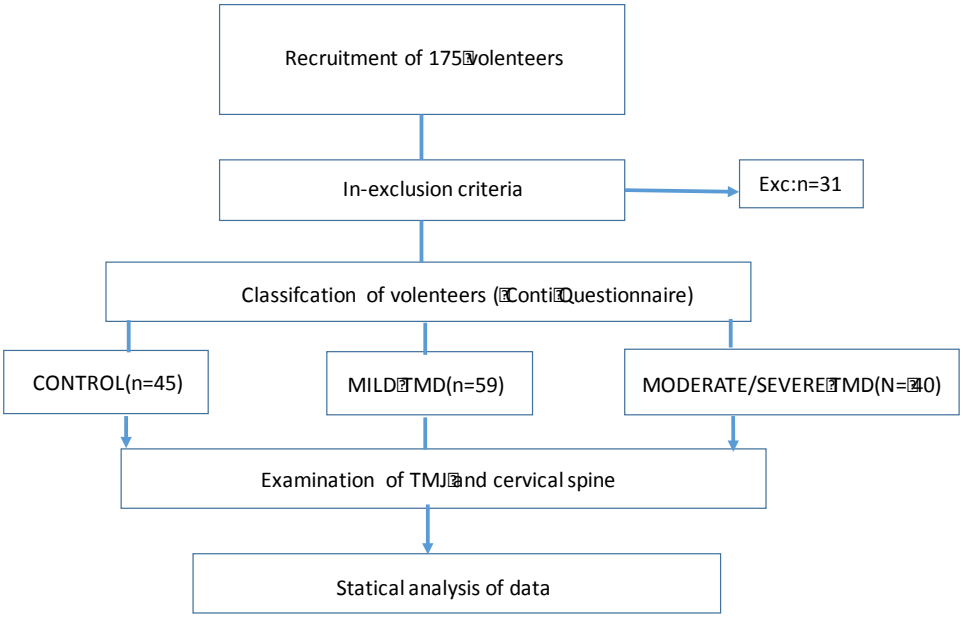

Figure 1 Flow chart of recruitment, classification and examination of the volunteers

Procedure

Assessment for TMD was carried out by the first investigator using the RDC/TMD Classification to identify volunteers fulfilling criteria for Axis I according to the procedure described for TMJ measurement (see below). To exclude subjects with central sensitization which may be potentially associated with false positive musculoskeletal function tests during physical examination, the GCPS (Axis II of RDC/TMD) was used (see exclusion criteria). The first examiner also administered the CAQ. Subjects with a CAQ rating equal or less than 3 with TMD signs were allocated to the group NO TMD, while subjects with a CAQ score of 4 to 8 were allocated to the group MILD TMD. Subjects with a score greater than 8 were allocated to group MODERATE/SEVERE TMD.

Following group allocation, two additional investigators, who were physiotherapists each with more than 3-years clinical experience, examined the TMJs and cervical spine of each subject. To ensure consistency, examiners undertook a training program supervised by an experienced clinician/researcher on 50 volunteers. Each examiner was blind to group allocation and to each other.

Measurements

Temporomandibular Joint

RDC/TMD Axis I comprises measurement of physiological movements of the TMJ's, joint sounds, and mechanical pressure pain thresholds (PPT).

Physiological movements included mouth opening (range and deviation), lateropulsion (lateral shift) to each side and retrusion (active mandible retraction) measured by a 10cm ruler. The Inter- and intrarater reliability for these measurements has been shown as moderate to excellent (ICC=0.68-0.99) (Dworkin et al., 1990; Walker et al., 2000).

Joint sounds were identified during mouth opening and closing using a stethoscope applied laterally over the TMJ. This method has been shown to be acceptable with kappa value 0.61 (Dworkin et al., 1990).

Mechanical pressure pain threshold (PPT) was measured using a pressure algometer (Wagner instruments, Force dial FDK 10) to evaluate mechanosensitivity overlying the Masseter and Temporalis Anterior muscles. Evaluation of the sensitivity of the lateral pole of the TMJ was determined by palpation with the index finger, while the posterior condyle pole was palpated with the little finger in the ear. Pain during jaw movements and finger palpation was interpreted by using a Colored Analogue Scale (CAS), which has been shown to be reliable (Bulloch et al., 2009). The CAS is similar to the Visual Analogue Scale (VAS) in respect to execution (Bulloch et al., 2009) but pain intensity is chosen by the subject according to intensity of red color on a 10cm ruler, wherein the pain intensity (Scale from 0 to 10) is then identified from the reverse side of the ruler.

Cervical spine

Examination of the cervical spine consisted of the NDI, cervical range of motion (ROM), Flexion Rotation Test (FRT), PPT and the craniocervical flexion test (CCFT).

The Neck Disability Index (NDI) is a valid and reliable measure (Vernon, 2008; Cramer et al., 2014), with score ranging from 0 to 50 (with 50 indicating severe pain and disability).

Active cervical ROM was measured with the Keno^{H}-cervical measurement instrument (Kunto- valine Oy & David Fitness & Medical Ltd, Helsinki, Finland), which is a valid and reliable instrument (Audette et al., 2010). This device was used to measure active cervical spine ROM through all cardinal planes as far as possible within comfortable limits in a seated neutral upright posture. Pain during each movement was assessed using the CAS.

Mechanical pressure pain threshold (PPT) was assessed over the mid belly of upper trapezius and inferior capitis oblique muscle by an algometer (Wagner instruments Model FPK 5). Pressure was applied at a constant rate of approximately 1 kg/cm2/s. To reduce the time taken for data collection and the burden on subjects, only two trials were taken for each muscle and averaged for analysis. PPT has been shown to be a valid and reliable method to measure mechanosensitivity (Grossi et al., 2011; Persson et al., 2004).

The flexion rotation test (FRT) has been shown to be a valid and reliable measure of upper cervical movement (Hall and Robinson, 2004; Hall et al., 2008), predominantly occurring at the C1/2 vertebral segment (Takasaki et al., 2011), and was carried out according to previously published guidelines (Hall and Robinson, 2004). ROM during the FRT was determined by a digital goniometer (*Halo Medical Device*) which was fixed to the apex of the subjects head when their neck was fully flexed and maintained in the horizontal plane.

The craniocervical flexion test (CCFT) was used to measure endurance and synergy of deep cervical flexor muscles by using a pressure stabilizer biofeedback device (*Chattanooga, USA) (*Jull et al., 2008). The testing procedure followed the protocol described by Hudswell et al. (2005). Subjects lay in supine position and were instructed to perform craniocervical flexion in five progressive stages increasing pressure from baseline of 20 to 30mm Hg. Subjects were instructed to hold each stage for 10 s, with a 10 s rest between stages. The pressure level at which the subject was able to hold for 10 s without palpable activity of superficial flexors, was documented by the examiner. This test shows high interrater reliability with intraclass correlation coefficients of 0.91 (95% confidence interval, 0.83-0.96) (Arumugam et al 2011) and good construct validity when compared with elecromyography (Falla et al 2006)

Unilateral and central posteroanterior passive accessory movements (PAM) were used to assess segmental mobility and mechanosensitivity from C1 to C3. The testing procedure followed the protocol described by Zito et al (2006) and Hall et al. (2010). Joint stiffness and pain were each rated as present or not. Hall et al. (2010) reported good reliability for this method of evaluation. The number of positive signs was summed up and is referred to as the variable “number of PAMs”

The protocol followed the Ethical Principles for Medical Research Involving Human Subjects as formulated in the Declaration of Helsinki and was accepted by the ethics commission of the University of Applied Science Osnabrück in Germany.

Statistical Analysis

All data were evaluated using *IBM SPSS Statistics 20. P-values below* $p<0.05$ were considered significant. Oneway Analysis of variance and Chi^2 was used to test for differences in baseline characteristics between subgroups of participants. For bivariate correlation Pearson´s correlation coefficient was used. All outcome variables were entered into linear regression models as dependent variables with TMD group membership as independent variable. Deviation of the data from normality was checked by inspecting normality plots such as quantile-quantile plots. The majority of the variables were approximately normally distributed. Additionally, assumptions for the regression model were checked. In general, assumptions were not violated so that we decided to perform the regression model. Outcome variables that assessed bilateral measurements were combined to one variable by calculating their mean as none of the side differences were significant. Effects of the linear regression models are given both in original units and as effects sizes according to Cohen (<0.2 no effect, 0.2-0.5 small effect, 0.5-0.8 moderate, 0.8>large effect) in order to allow evaluation of clinical relevance. Additionally, we added age and gender as covariates into the model as potential confounders. If p-values of covariates according to t-statistics were >0.1 and betas changed less than 10% then covariates were withdrawn from the model.

Results

Subject characteristics are shown in Table 1. Mean age was not significantly different between groups, however this was not the case for the number of female subjects and predictably the mean score on the CAQ scale (Table 2). The amount of TMD sub-types (arthrogenous, myogenous, mixed) is presented in Table 1.

Table 1
Baseline: mean values for age and CAQ scores, with number and percentage of females. CONTROL: Subjects with CAQ score ≤ 3, mild TMD: CAQ score 4-8, moderate/severe TMD: CAQ score >8. Sub-classification into myogenic, arthrogenic and mixed sub-groups after the TMD examination according to the RCD/TMD.

	CONTROL (N=45)	**mild TMD (n=59)**	**moderate/ severe TMD (n=40)**	**p-value**

CAQ	1.08(1.08)	5.78(1.43)	11.3(2.83)	p<0.001
Acute pain Mean(SD)	0.7 (0.6)	1.3 (1.13)	2.12 (1.7)	p<0.001
Age Mean(SD)	33(8.71)	33.21(10.)	37.25 (13.78)	p=0.14
Gender Fermale	30 (67%)	18 (30%)	34 (85%)	p=0.06
RCD/TMD Classif. **. Myogen (%)** **. Artrogen (%)** **. Mixed (%)**		14 (14%) 12 (12%) 33 (33%)	5 (5%) 5 (5%) 30 (30%)	

Figure 2 depicts the association between general cervical dysfunction and TMD dysfunction. The correlation between NDI and CAQ scores ($r=0.55$, $p<0.001$) indicates that the greater the cervical impairment the greater the degree of the TMD impairment.

In figure 3 raw scores and means according to TMD subgroups are depicted. a) represents cervical ROM, b) represents pain during cervical movement c) represents mechanosensitivity, number of PAM signs and muscular endurance. In 3a) it is shown, that in all cardinal planes of cervical ROM (flexion, extension, lateral flexion, rotation) group NO TMD shows larger mean ROM than the groups with mild or moderate/severe TMD. For the FRT, no relevant difference between the groups were identified. Figure 3b) indicates that subjects with TMD reported more pain during the examination of all cervical movement in all directions. Figure 3c) shows lower levels of mechanosensitivity in upper trapezius and obliquus capitis inferior muscles in both TMD groups compared to group NO TMD. In addition, the number of positive signs on PAM's was found to increase with the severity of TMD. For the muscular endurance of deep cervical flexor muscles, assessed with the CCFT, group NOTMD and group mild TMD showed similar mean scores. Only group moderate/severe TMD were found to have lower scores on the CCFT indicating poorer muscle function. In general, a clear pattern can be seen: The control group NO TMD is consistently the least affected and the moderate/severe TMD group the most affected in terms of cervical musculoskeletal dysfunction. This indicates that the more severe the TMD, the greater the level of cervical dysfunction on all tests.

In Table 3 the results of the linear regression models are depicted and confirm findings from fig 3a-c. In general, small effects for ROM can be seen. In particular, with respect to lateral flexion, a small effect ($p=0.03$) exists between groups NO TMD and mild TMD. This is also true for rotation, where a small effect size can be seen between groups NO TMD and

moderate TMD (p=0.04). The presence of pain during cervical ROM shows in general small to large effect sizes. The groups NO TMD and mild TMD reveal comparatively less pain than the group moderate/severe TMD. For mechanosensitivity, medium effect sizes can be seen between groups NO TMD and moderate/severe TMD with a high level of significance (p<0.001). A clear pattern can be seen: The group NO TMD is consistently the least affected and the moderate/severe group the most affected in terms of cervical dysfunction. This indicates that the more severe the TMD the more affected are single measurements of cervical dysfunction.

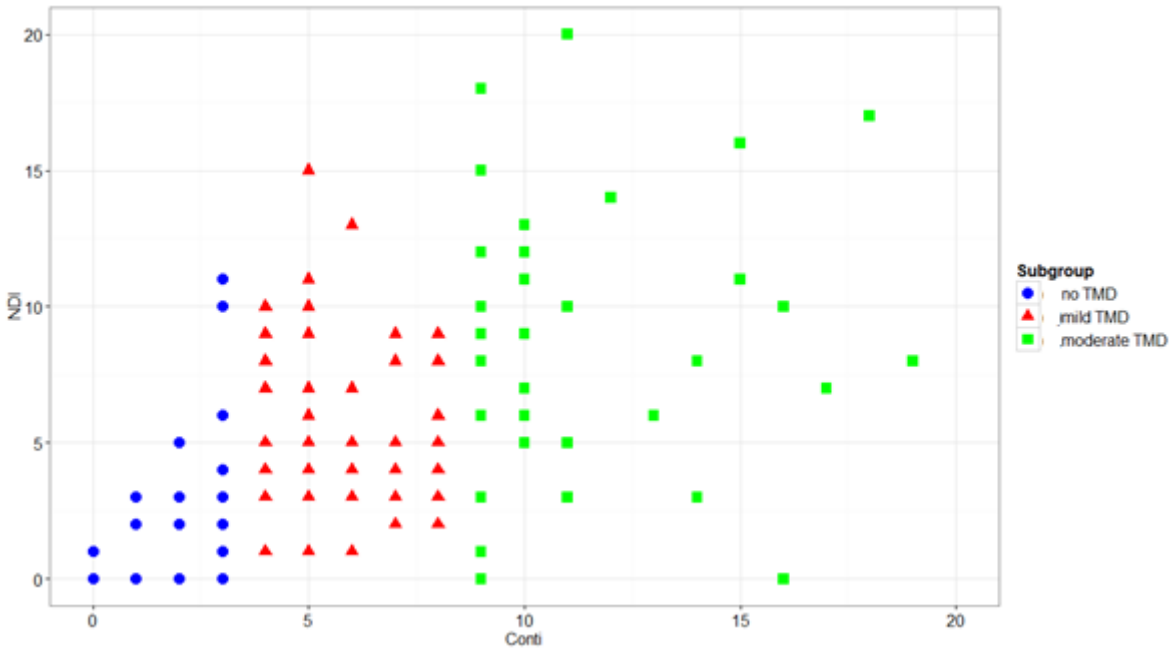

Figure 2 Correlation between Neck disability Index (NDI) and Conti Amnestic Questionnaire (CAQ) related to subgroups No TMD, mild TMD and moderate/severe TMD.(r=0.55, p<0.001),

Figure3a-c: raw scores and means according to TMD subgroups are depicted. A) represents cervical ROM, b) represents pain at ROM c) represents mechanosensitivity, number of cervical signs and muscular endurance

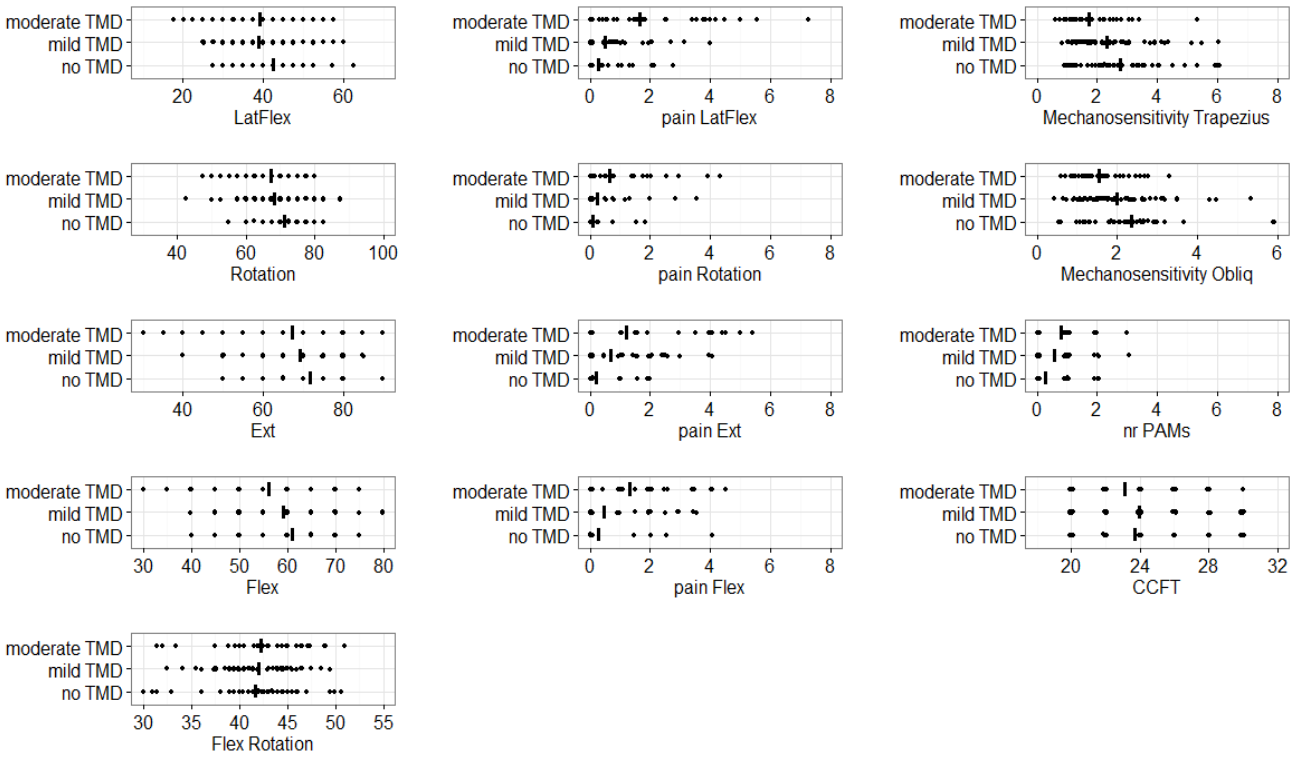

Table 3: results of linear regression models are presented for all cervical measurements. Mean differences (in original values) for all subgroups comparisons including confidence intervals and p-values are given. The column "Effects size" represent the effect sizes according to Cohen and are to be interpreted as: <0.2 no effect, <0.5 small effect, <0.8 moderate effect, ≥0.8 large effect. Effects at least reaching "small" are marked green and sig. effects red. Effects are adjusted for age and gender if necessary. Example of reading: the comparison "No TMD vs mild TMD" means that the average ROM in No TMD group is 4° greater than in the group mild TMD. This represents a small effect size. P-values ;*** means significant and ** extreme significant.**

	comparison	mean difference	lower CI	upper	effect size	p-value
Extension	mild TMD vs moderate TMD	1.34	-3.7	6.39	0.1	0.6
	No TMD vs mild TMD	4	-0.91	8.91	0.3	0.11
	No TMD vs moderate TMD	5.34	-0.09	10.78	0.4	0.06
Flexion	mild TMD vs moderate TMD	1.44	-2.46	5.33	0.15	0.47
	No TMD vs mild TMD	2.63	-1.16	6.42	0.27	0.18
	No TMD vs moderate TMD	4.07	-0.13	8.26	0.41	0.06
Lateral flexion	mild TMD vs moderate TMD	-0.31	-3.83	3.21	-0.03	0.86
	No TMD vs mild TMD	3.81	0.36	7.27	0.43	**0.03***
	No TMD vs moderate TMD	3.5	-0.29	7.3	0.4	0.07
Rotation	mild TMD vs moderate TMD	0.89	-2.74	4.51	0.1	0.63

	No TMD vs mild TMD	3.2	-0.3	6.7	0.35	0.08
	No TMD vs moderate TMD	4.08	0.24	7.93	0.45	**0.04***
Flex Rotation	mild TMD vs moderate TMD	-0.1	-2.7	2.5	-0.02	0.94
	No TMD vs mild TMD	0.73	-1.8	3.26	0.11	0.57
	No TMD vs moderate TMD	0.63	-2.17	3.43	0.1	0.66
Pain Extension	mild TMD vs moderate TMD	-0.44	-0.94	0.06	-0.34	0.09
	No TMD vs mild TMD	-0.5	-0.99	-0.01	-0.39	**0.05***
	No TMD vs moderate TMD	-0.94	-1.49	-0.4	-0.74	**<0.001****
Pain Flexion	mild TMD vs moderate TMD	-0.81	-1.27	-0.34	-0.66	**<0.001****
	No TMD vs mild TMD	-0.29	-0.75	0.16	-0.24	0.21
	No TMD vs moderate TMD	-1.1	-1.6	-0.6	-0.9	**<0.001****
Pain Lat flex	mild TMD vs moderate TMD	-1.08	-1.57	-0.59	0.48	**<0.001****
	No TMD vs mild TMD	-0.24	-0.71	0.24	0.18	0.33
	No TMD vs moderate TMD	-1.32	-1.84	-0.79	0.65	**<0.001****
Pain Rotation	mild TMD vs moderate TMD	-0.32	-0.62	-0.02	-0.41	**0.04***
	No TMD vs mild TMD	-0.19	-0.48	0.1	-0.24	0.21
	No TMD vs moderate TMD	-0.51	-0.84	-0.19	-0.65	**<0.001****
Mechanosensitivity Trapezius	mild TMD vs moderate TMD	0.62	0.2	1.04	0.5	**<0.001****
	No TMD vs mild TMD	0.2	-0.21	0.61	0.17	0.33
	No TMD vs moderate TMD	0.83	0.37	1.28	0.67	**<0.001****
Mechanosensitivity Obliqus	mild TMD vs moderate TMD	0.48	0.14	0.83	0.48	**0.01***
	No TMD vs mild TMD	0.18	-0.16	0.52	0.18	0.29
	No TMD vs moderate TMD	0.66	0.29	1.04	0.65	**<0.001****
Number positive PAMs	mild TMD vs moderate TMD	-0.23	0.54	-0.007	-0.3	**0.14**
	No TMD vs mild TMD	-0.25	-0.55	0.05	-0.33	0.1
	No TMD vs moderate TMD	-0.48	-0.81	-0.15	-0.63	**<0.001****
CCFT	mild TMD vs moderate TMD	0.41	-1.14	1.96	0.11	0.61
	No TMD vs mild TMD	-0.01	-1.52	1.5	0	0.99

	No TMD vs moderate TMD	0.4	-1.27	2.07	0.1	0.64

Discussion

This study found a correlation between neck disability and severity of TMD dysfunction and pain measured with CAQ. These findings are consistent with and compliment the report by Olivo et al. (2010) which used the NDI and the Jaw Disability Index (JDI). In other words, the more severe the degree of TMD, the more impairments subjects with neck disability report.

Regarding active cervical ROM, the current study found that subjects with TMD show higher levels of impairments in ROM in all directions (flexion, extension, lateral flexion, rotation) in comparison to healthy subjects. However, only examining the reported pain during cervical movements showed statistically significant findings: Pain during cervical motion increases with the severity of TMD. The comparison between healthy subjects and those with no TMD and subjects with moderate TMD and the comparison between mild TMD and moderate TMD both showed significant differences between groups for pain during movement in all cardinal planes.

While the FRT and CCFT did not show differences between groups, mechanosensitivity in upper trapezius and obliquus capitis inferior muscles was lower in both TMD groups compared to group NO TMD. The medium effects in mechanosensitivity of upper trapezius and obliquus capitis inferior muscles between groups NO TMD and MODERATE/SEVERE TMD was highly significance ($p<0.001$). These results might suggest that people with TMD have lower levels of mechanosensitivity in the neck region (when measured over the upper trapezius and obliquus capitis inferior muscles) compared to people without TMD. These findings agree with De Laat et al. (1998), who found significantly more tender points in upper trapezius muscle in subjects with TMD compared to controls.

The findings in relation to the CCFT do agree with finding of Armijo-Olivo et al (2011). In that report increased electromyographic activity of the superficial cervical flexor muscles was identified during the CCFT in subjects with myogenous and mixed TMD also classified after the RCD/TMD. They suspected altered motor patterns during the CCFT attributable to TMD. However, the results of the current study indicate only a very low to no effect size when comparing groups which means that there was no significant difference between the different TMD groups (Table 3).

Interestingly, there were no significant differences between groups for the FRT (Table 3).

However, these findings are not in agreement with previous reports (Armijo-Olivo et al., 2006; von Piekartz and Hall, 2013; Grondin et al 2015). A previous study has demonstrated the high sensitivity and specificity of the FRT in detecting upper cervical movement impairment in patients with CGH (Hall et al., 2010). The current study failed to find a difference in in upper cervical rotation between groups. Hence there appears to be no clear impairment of (joint) movement in the upper cervical spine in people with TMD. ROM during the FRT is primarily localized to the C1/2 segment in normal people (Takasaki et al, 2011), however ROM during the FRT is reduced in the presence of cervicogenic headache (Ogince, 2007; Hall & Robinson 2004) and is also reduced in people with TMD with features of cervicogenic headache (von Piekartz et al, 2013). Previously it has been shown that people with migraine headache do not have an impairment of movement during the FRT (Hall et al, 2010). Hence the presence of upper cervical pain, particularly referred cervicogenic headache seems to be a factor that induces change in ROM during the FRT. One study has demonstrated an impairment of movement on the FRT in people with TMD without headache (Grondin et al 2014), but it was not defined whether subjects in that study had cervical spine disorders associated with TMD. Further studies are required to confirm the link between TMD and impairment of ROM on the FRT. Hence, with respect to the current study, where the sample inclusion criteria were based on subjects having TMD signs without chronic pain which was not involving the cervical region, subjects may have had a different pattern of cervical impairment that did not affect the FRT when compared to previous studies that examined people with different forms of TMD. Thus, the difference in subjects between the various studies reported so far might explain why the FRT and possibly also the CCFT were not significantly different in the 3 subgroups. As far as the authors are aware, there is no other published literature regarding this phenomenon. Therefore the results of our study lend credence to the notion (that requires further investigation) that clinicians should be aware that patients with clear TMJ signs (for example referred from a dentist or orthodontist) have differing cervical impairments to those patients with a cervical disorder such as CGH with associated TMD.

This study confirms that the presence of pain and TMD, is more frequently associated with cervical signs and suggests a dose response relationship between cervical signs and TMD-pain and disability. This study's finding is in accordance with previous research and provides further evidence for the functional relationship between the temporomandibular and neck region (Visscher et al., 2001; Armijo-Olivo and Magee, 2012). Furthermore, these results are consistent with the theory of the trigemino-cervical complex, which provides an anatomical and neurophysiological explanation for the relationship between the cervical and temporomandibular area. Giannakopoulos et al (2013) also reported that TMD and pain may

influence neck motor patterns which may consequently influence neck movement. Due to this interaction, it can be difficult to find the origin of dysfunction and pain in patients with TMD (Armijo-Olivo et al., 2006; von Piekartz and Hall, 2013). The present study highlights the complexity of identifying the origin of symptoms. In view of the fact that the temporomandibular and cervical region may influence each other, physical therapists need to be aware that patients with cardinal signs of TMD (altered ROM, TMJ sounds during movement, and increased unilateral muscle mechanosensitivity) show more clinical positive cervical test signs. This finding may be relevant when treating patients with persisting TMD dysfunction and pain as well as in the management of people with TMD.

It should be noted the proportion of females in group NO TMD (67%) and moderate/severe TMD (85%) was very high. In contrast, the mild TMD group consisted of more men. However, the high proportion of females in group moderate/severe TMD is consistent with studies reporting a greater prevalence of TMD in women than in men (Goncalves et al., 2011). The higher proportion of woman was considered in the statistical analysis by using gender stratification.

Limitations of this study need to be considered. Although the examination protocol for TMD classification was based on the RDC/TMD Axis I, not all tests were included. For instance, palpation of the lateral pterygoid muscle is not considered meaningful, as this muscle is painful to touch even in asymptomatic people (Türp et al., 2006). Furthermore, the palpation of the posterior digastric and stylohyoid muscles has little diagnostic validity. Therefore, the investigation of these muscles was not included. The emphasis in this study was on cardinal TMD signs, those that are most commonly described in clinical examination (LeResche, 1997; von Piekartz, 2015). It has to be noted that severity of TMD and subsequently group allocation was based on the CAQ whereas the RDC/TMD Axis I was used as a confirmation of TMD. In order to determine chronic pain, axis II of the RDC/ TMD was used. Clinical signs in combination with other pain-related psychosocial examination tools are defined as the minimum evaluation (Türp et al., 2006). Since the examination protocol is based on the RDC/ TMD Axis I, this protocol is considered to be acceptable as a diagnostic assessment for TMD classification.

Conclusion

This study revealed that more cervical impairments are found in people with more severe levels of TMD (based on RCD/TMD classification) in acute and sub-acute pain states. It was also demonstrated that people with mild and moderate TMD report more pain during cervical movements and lower mechanosensitivity over upper trapezius and obliquus capitis inferior

muscles. In contrast, the FRT and the CCFT were not impaired in people with TMD. These results suggest that people with acute and sub-acute TMD have a different pattern of cervical impairment to other forms of cervical spine musculoskeletal disorders which may also have associated TMD impairments such as cervicogenic headache. From this study we may conclude that people with TMD (with and without pain) have distinct patterns of cervical musculoskeletal impairments. Physical examination of the neck should be included when examining patients with TMD. Further investigation of cervical signs in TMD sub-types (arthrogenous, myogenous, mixed) as well as chronic TMD states is recommended.

References

Armijo-Olivo, S. & Magee, D. Cervical Musculoskeletal Impairments and Temporomandibular Disorders. Journal of oral & maxillofacial research, 2012, 3(4).

Armijo-Olivo, S., Magee, D. J., Parfitt, M., Major, P. & Thie, N. M. The association between the cervical spine, the stomatognathic system, and craniofacial pain: a critical review. Journal of orofacial pain, 2006, 20(4).

Armijo-Olivo, S., Silvestre, R., Fuentes, J., da Costa, B. R., Gadotti, I. C., Warren, S., Major, P. W., Thie, N. M. & Magee, D. J. Electromyographic activity of the cervical flexor muscles in patients with temporomandibular disorders while performing the craniocervical flexion test: a cross-sectional study. Physical therapy, 2011, 91(8), 1184-1197.

Audette, I., Dumas, J. P., Côté, J. N. & De Serres, S. J. Validity and between-day reliability of the cervical range of motion (CROM) device. Journal of orthopaedic & sports physical therapy, 2010, 40(5), 318-323.

Ballenberger, N., von Piekartz, H., Paris-Alemany, A., La Touche, R. & Angulo-Diaz-Parreño, S. Influence of different upper cervical positions on electromyography activity of the masticatory muscles. Journal of manipulative and physiological therapeutics, 2012, 35(4), 308-318.

Bevilaqua-Grossi D, Chaves TC, de Oliveira AS, Monteiro-Pedro V: Anamnestic index severity and signs and symptoms of TMD. J Cranio- mandib Pract 2006; 24:112-118.

Bevilaqua-Grossi, D., Chaves, T. C. & Oliveira, A. S. D. Cervical spine signs and symptoms: perpetuating rather than predisposing factors for temporomandibular disorders in women. Journal of Applied Oral Science, 2007, 15(4), 259-264.

Bogduk, N. Cervicogenic headache: anatomic basis and pathophysiologic mechanisms. Current pain and headache reports, 2001, 5(4), 382-386.

Bulloch, B., Garcia-Filion, P., Notricia, D., Bryson, M. & McConahay, T. Reliability of the color analog scale: repeatability of scores in traumatic and nontraumatic injuries. Academic Emergency Medicine, 2009, 16(5), 465-469.

Collins, S. L., Moore, R. A. & McQuay, H. J. The visual analogue pain intensity scale: what is moderate pain in millimeters? Pain, 1997, 72(1), 95-97.

CAQ, P. C. A., Ferreira, P. M., Pegoraro, L. F., CAQ, J. V. & Salvador, M. C. A cross-sectional study of prevalence and etiology of signs and symptoms of temporomandibular

disorders in high school and university students. Journal of orofacial pain, 1996, 10(3).124-141

Conti PC, Ferreira PM, Pegoraro LF, Conti JV, Salvador MC: A crosssecional study of prevalence and etiology of signs and symptoms of temporo- mandibular disorders in high school and university students. *J Orofac Pain* 1996, 10(3):254-262.

Cramer, H., Lauche, R., Langhorst, J., Dobos, G. J. & Michalsen, A. Validation of the German version of the Neck Disability Index (NDI). BMC musculoskeletal disorders, 2014, 15(1), 91.

De Laat, A., Meuleman, H., Stevens, A. & Verbeke, G. Correlation between cervical spine and temporomandibular disorders. Clinical oral investigations, 1998, 2(2), 54-57.

Dworkin, S. F., LeResche, L., DeRouen, T. & Von Korff, M. Assessing clinical signs of temporomandibular disorders: reliability of clinical examiners.The Journal of prosthetic dentistry, 1990, 63(5), 574-579.

Falla D, Jull G, O'Leary S, Dall'Alba P. Further evaluation ofan EMG technique for assessment of the deep cervical flexormuscles. J Electromyogr Kinesiol 2006;16:621-8.

Giannakopoulos NN, Hellmann D, Schmitter M, Krüger B, Hauser T, Schindler HJ. Neuromuscular interaction of jaw and neck muscles during jaw clenching J Orofac Pain. 2013 Winter;27(1):61-71

Grondin F, Hall T, Laurentjoye M, Ella B. Upper cervical range of motion is impaired in patients with temporomandibular disorders. Cranio. 2015 May;33(2):91-9

Gesch, D., Bernhardt, O., Alte, D., Schwahn, C., Kocher, T., John, U. & Hensel, E. Prevalence of signs and symptoms of temporomandibular disorders in an urban and rural German population: results of a population-based Study of Health in Pomerania. Quintessence international, 2004, 35(2).

Grossi, D. B., Chaves, T. C., Gonçalves, M. C., Moreira, V. C., Canonica, A. C., Florencio, L. L., Bordini, C. A., Speciali, J. G. & Bigal, M. E. Pressure pain threshold in the craniocervical muscles of women with episodic and chronic migraine: a controlled study. Arquivos de neuro-psiquiatria, 2011, 69(4), 607-612.

Hall, T. & Robinson, K. The flexion–rotation test and active cervical mobility—a comparative measurement study in cervicogenic headache. Manual therapy, 2004, 9(4), 197-202.

Hall, T. M., Robinson, K. W., Fujinawa, O., Akasaka, K. & Pyne, E. A. Intertester reliability and diagnostic validity of the cervical flexion-rotation test. Journal of manipulative and physiological therapeutics, 2008, 31(4), 293-300.

Hall, T., Briffa, K., Hopper, D. & Robinson, K. Reliability of manual examination and frequency of symptomatic cervical motion segment dysfunction in cervicogenic headache. Manual therapy, 2010, 15(6), 542-546.

Hudswell, S., Von Mengersen, M. & Lucas, N. The cranio-cervical flexion test using pressure biofeedback: A useful measure of cervical dysfunction in the clinical setting? International journal of osteopathic medicine, 2005, 8(3), 98-105.

Jull, G. A., O'Leary, S. P. & Falla, D. L. Clinical assessment of the deep cervical flexor muscles: the craniocervical flexion test. Journal of manipulative and physiological therapeutics, 2008, 31(7), 525-533.

Jull, G., Barrett, C., Magee, R. & Ho, P. Further clinical clarification of the muscle dysfunction in cervical headache. Cephalalgia, 1999, 19(3), 179-185.

La Touche, R., París-Alemany, A., von Piekartz, H., Mannheimer, J. S., Fernández-Carnero, J. & Rocabado, M. The influence of cranio-cervical posture on maximal mouth opening and pressure pain threshold in patients with myofascial temporomandibular pain disorders. The Clinical journal of pain, 2011, 27(1), 48-55.

LeResche, L. Epidemiology of temporomandibular disorders: implications for the investigation of etiologic factors. Critical Reviews in Oral Biology & Medicine, 1997, 8(3), 291-305.

Olivo, S. A., Fuentes, J., Major, P. W., Warren, S., Thie, N. M. R. & Magee, D. J. The association between neck disability and jaw disability. Journal of oral rehabilitation, 2010, 37(9), 670-679.

Persson, A., Brogardh, C. & Sjolund, B. H. Tender or not tender: test-retest repeatability of pressure pain thresholds in the trapezius and deltoid muscles of healthy women. Journal of Rehabilitation Medicine, 2004, 36(1), 17-27.

Piekartz von, H. & Hall, T. Orofacial manual therapy imprhbgoves cervical movement impairment associated with headache and features of temporomandibular dysfunction: A randomized controlled trial. Manual therapy, 2013, 18(4), 345-350.

Piekartz von, H. & Lüdtke, K. Effect of treatment of temporomandibular disorders (TMD) in patients with cervicogenic headache: a single-blind, randomized controlled study. CRANIO, 2011, 29(1), 43-56.

Piekartz von, H. Temporomandibular Disorders: Neuromusculoskeletal Assessment and Management in Grieve's Modern Musculoskeletal Physiotherapy, 4th Edition , Jull G, Moor A, Falla D,Lewis, McCarthy C, Sterling M , 2015, 433-444.

Svensson, P. & Graven-Nielsen, T. Craniofacial Muscle Pain: Review of Mechanisms and Clinical Manifestations. J OROFAC PAIN, 2001, 15, 117-145.

Takasaki, H., Hall, T., Oshiro, S., Kaneko, S., Ikemoto, Y. & Jull, G. Normal kinematics of the upper cervical spine during the Flexion–Rotation Test–In vivo measurements using magnetic resonance imaging. Manual therapy, 2011, 16(2), 167-171.

Thilander, B., Rubio, G., Pena, L. & de Mayorga, C. Prevalence of temporomandibular dysfunction and its association with malocclusion in children and adolescents: an epidemiologic study related to specified stages of dental development. The Angle Orthodontist, 2002, 72(2), 146-154.

Tuncer, A. B., Ergun, N., Tuncer, A. H. & Karahan, S. Effectiveness of manual therapy and home physical therapy in patients with temporomandibular disorders: A randomized controlled trial. Journal of bodywork and movement therapies, 2013, 17(3), 302-308.

Türp, J. C., Hugger, A., Nilges, P., Hugger, S., Siegert, J., Busche, E. & Schindler, H. J. [Recommendations for the standardized evaluation and classification of painful temporomandibular disorders: an update]. Schmerz (Berlin, Germany), 2006, 20(6), 481-489.

Vernon, H. The Neck Disability Index: state-of-the-art, 1991-2008. Journal of manipulative and physiological therapeutics, 2008, 31(7), 491-502.

Visscher, C. M., Lobbezoo, F., De Boer, W., Van Der Zaag, J. & Naeije, M. Prevalence of cervical spinal pain in craniomandibular pain patients.European journal of oral sciences, 2001, 109(2), 76-80.

Von Korff M, Ormel J, Keefe FJ, Dworkin SF: Grading the severity of chronic pain. *Pain* 1992; 50(2):133-149.

Walker, N., Bohannon, R. W. & Cameron, D. Discriminant validity of temporomandibular joint range of motion measurements obtained with a ruler.Journal of Orthopaedic & Sports Physical Therapy, 2000, 30(8), 484-492.

Wijer de A., Steenks MH., de Leeuw JR. Symptoms of the cervical spine in temporomandibular and cervical spine disorders. J Oral Rehabil. 1996 Nov;23(11):742-50.

Zito, G., Jull, G., & Story, I. Clinical tests of musculoskeletal dysfunction in the diagnosis of cervicogenic headache. Manual therapy, 2006, 11(2), 118-129.