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ORIGINAL ARTICLE

Women with more severe degrees of temporomandibular disorder exhibit an increase in temperature over the temporomandibular joint

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KEYWORDS

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Abstract *Aim:* The purpose of the present study was to correlate the degree of temporomandibular disorder (TMD) severity and skin temperatures over the temporomandibular joint (TMJ) and masseter and anterior temporalis muscles.

Materials and methods: This blind cross-sectional study involved 60 women aged 18–40 years. The volunteers were allocated to groups based on Fonseca anamnestic index (FAI) score: no TMD, mild TMD, moderate TMD, and severe TMD ($n = 15$ each). All volunteers underwent infrared thermography for the determination of skin temperatures over the TMJ, masseter and anterior temporalis muscles. The Shapiro–Wilk test was used to determine the normality of the data. The Kruskal–Wallis test, followed by Dunn's test, was used for comparisons among groups according to TMD severity. Spearman's correlation coefficients were calculated to determine the strength of associations among variables.

Results: Weak, positive, significant associations were found between FAI score and skin temperatures over the left TMJ ($rs = 0.195$, $p = 0.009$) and right TMJ ($rs = 0.238$, $p = 0.001$). Temperatures over the right and left TMJ were significantly higher in groups with more severe TMD ($p < 0.05$).

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Conclusion: FAI score was associated with skin temperature over the TMJ, as determined by infrared thermography, in this sample. Women with more severe TMD demonstrated a bilateral increase in skin temperature.

1. Introduction

Temporomandibular disorder (TMD) is characterized by myofascial and/or joint pain, joint noises, lack of motor coordination, and a limited range of mandibular motion (Manfredini et al., 2011; Peck et al., 2008). Conceptually, TMD is a complex pathological condition that can affect different structures of the stomatognathic system, such as the temporomandibular joint (TMJ) and masticatory muscles (Leeuw, 2008).

Due to the particular characteristics of TMD, such as its multifactorial etiology and the different structures involved in the pathological process, the evaluation of affected patients plays a determinant role in the clinical management of signs and symptoms and is directly related to the effectiveness of the rehabilitation process (Manfredini et al., 2011; McNeill, 1997; Oral et al., 2009). Several measures have been employed for the diagnosis and evaluation of TMD, such as the Research Diagnostic Criteria for Temporomandibular Disorders, radiography, magnetic nuclear resonance imaging, computed tomography, and electromyography (Look et al., 2010; Rodrigues-Bigaton et al., 2008). The Fonseca anamnestic index (FAI) is a simple measure based on the Helkimo index that has been employed to identify the degree of TMD severity in the Brazilian population (Chaves et al., 2008; Fonseca et al., 1994).

Individuals with TMD exhibit circulatory and/or autonomic alterations. Thus, infrared thermography has been employed for the evaluation of this condition (Barão et al., 2011; Haddad et al., 2012). This non-invasive assessment method allows the measurement of skin temperature based on infrared radiation emitted by bodies with temperatures above absolute zero (Brioschi et al., 2003). Recent studies have found that skin temperature over the TMJ is increased in individuals with joint pain (Rodrigues-Bigaton et al., 2013), whereas skin temperature over the masticatory muscles is reduced in those with myofascial pain (Barão et al., 2011; Rodrigues-Bigaton et al., 2014). Moreover, individuals with TMD exhibit greater asymmetry in skin temperature than do those without this condition (Gratt and Anbar, 1998; Gratt and Sickles, 1993; Gratt et al., 1994a; McBeth and Gratt, 1996).

Although several studies have investigated the use of infrared thermography for the evaluation of individuals with TMD (Barão et al., 2011; Costa et al., 2013; Haddad et al., 2012; Rodrigues-Bigaton et al., 2013, 2014), the behavior of skin temperature as a function of TMD severity has not been determined. Thus, the aim of the present study was to correlate the degree of TMD severity with skin temperatures over the TMJ and masticatory muscles. The hypothesis was that significant associations would be found among the variables investigated.

2. Materials and methods

2.1. Ethical considerations

The Human Research Ethics Committee of the Methodist University of Piracicaba, São Paulo, Brazil, approved the study procedure (protocol No. 15/11). Volunteers agreed to participate by signing a statement of informed consent.

2.2. Study design

A blind cross-sectional study was performed. One physiotherapist administered the FAI, another captured and analyzed the infrared images, and a third was in charge of data processing and analysis.

2.3. Sample size calculation

The sample size was calculated using Ene software (version 3.0; Autonomic University of Barcelona, Barcelona, Spain). Based on data reported by Pogrel et al. (1989), absolute skin temperature over the TMJ was considered to be the outcome. The calculation was based on the detection of a difference of 0.97 °C among groups, a standard deviation of 0.83 °C, a statistical power of 80%, and an alpha value of 0.05. A minimum of 13 volunteers per group were needed. To compensate for possible losses, 15 volunteers were selected for each group.

2.4. Sample

Seventy female volunteers aged 18–40 years were recruited from the university community in the cities of Piracicaba and Americana (SP, Brazil). The exclusion criteria were body mass index (BMI) > 25 kg/m^2, use of total or partial dentures, history of trauma to the face or TMJ, systemic disease (arthritis, arthrosis, or neuromuscular disorder), and current physical therapy, dental treatment, and/or medication use (analgesic, anti-inflammatory, or muscle relaxant).

Only women were selected for the study due to the high prevalence rate of TMD in female individuals (Oliveira et al., 2006). According to Bagis et al. (2012), the greater frequency of symptoms in female individuals is due to anatomic, biological, and hormonal factors.

2.5. Fonseca anamnestic index

The FAI was used to determine the severity of signs and symptoms of TMD. This instrument, one of few assessment tools developed in Portuguese for this purpose, is composed of 10 questions. Responses of "yes" are given 10 points, responses of "sometimes" are given 5 points, and responses of "no" are given 0 points. The sum of points allows the classification of TMD severity as absent (0–15 points), mild (20–45 points), moderate (50–65 points), or severe (70–100 points) (Bevilaqua-Grossi et al., 2006; Chaves et al., 2008; Fonseca et al., 1994). Table 1 lists FAI questions, as translated into English by Campos et al. (2009).

An examiner instructed the volunteers how to fill out the questionnaire. Each volunteer answered the questionnaire independently in a well-lit, climate-controlled room with no time constraint.

2.6. Infrared thermography

Prior to examination, volunteers remained in a room for 20 min with the temperature controlled at 22 ± 1 °C and without heat-generating electrical equipment or the incidence of air or sunlight. The room was lit with fluorescent bulbs. The volunteers had been instructed to avoid hot baths or showers; the use of topical agents, creams or talc; the practice of vigorous physical exercise; and the ingestion of stimulating substances, such as caffeine, chocolate or nasal decongestants, for at least 2 h prior to the exam (Costa et al., 2013; Dibai Filho et al., 2012).

During the examination, the volunteer remained seated in a chair with her trunk erect, feet planted on the ground, and hands supported on the thighs, with the Frankfurt plane parallel to the ground. The facial region to be evaluated was free of clothing and personal objects, such as earrings, necklaces, or other accessories. The hair was tied back when necessary.

A T360 thermal camera (FLIR Systems, Wilsonville, OR, USA) was used to capture the images, with emission set at 0.98. The device was stabilized for 10 min prior to the reading. Image capture was performed at a distance of 100 cm from the volunteer to enable framing of the regions to be evaluated (Costa et al., 2013).

2.7. Analysis of infrared images

A single evaluator blinded to TMD severity conducted all analyses. Image analysis was performed with the aid of QuickReport software (version 1.1; FLIR Systems).

Styrofoam markers were used for the measurement of temperature over the masticatory muscles due to the isolating characteristics of the material. The markers were employed to delimit the origins and insertions of the muscles for subsequent analysis of the infrared images. For the anterior temporalis muscle, one marker was placed on the frontal bone immediately over the belly of the muscle and another marker was placed next to the lateral commissure of the eyelids. For the masseter muscle, one marker was placed on the zygomatic arch and another was placed on the lateral face of the mandibular angle.

Muscle area was measured using the "area" tool of the analysis software, generating a mean temperature of the area between the Styrofoam markers (Fig. 1). Regarding the reliability of this type of analysis, Rodrigues-Bigaton et al. (2014) reported excellent intra- and inter-examiner agreement using intraclass correlation coefficients.

Point measurement was used for the determination of skin temperature over the TMJ. The external auditory meatus was used as the parameter for joint location, as the TMJ is typically found in front of this anatomic structure (Fig. 2). This infrared image analysis method has exhibited excellent intra- and inter-examiner reliability (Rodrigues-Bigaton et al., 2013).

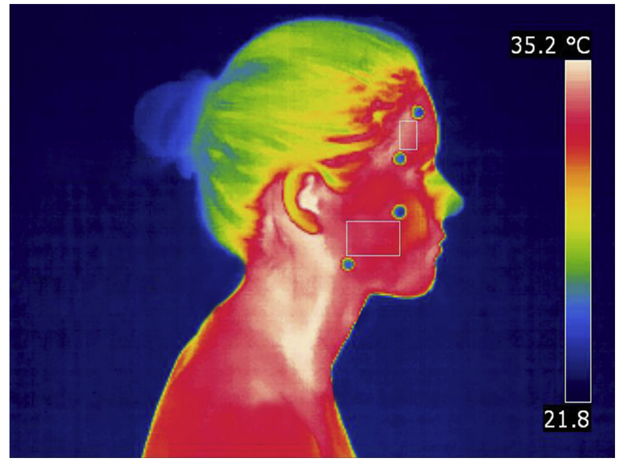

Figure 1 Analysis in area of the masseter and anterior temporalis muscles in the infrared image.

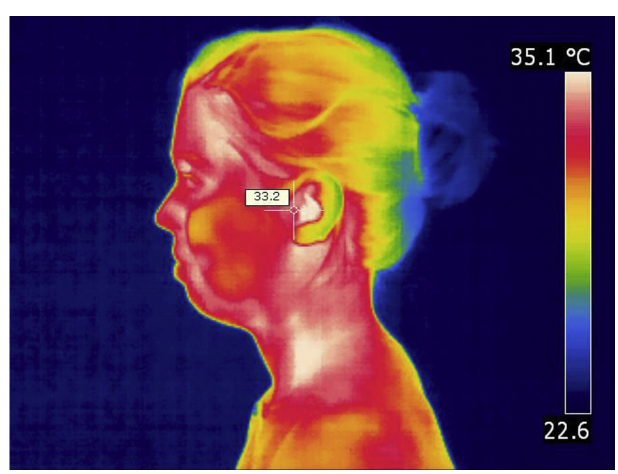

Figure 2 Punctual analysis of the temporomandibular joint in the infrared image.

Table 1 Questions on Fonseca anamnestic index translated into English by Campos et al. (2009).

Numbers	Questions
1	Do you have difficulty opening your mouth wide?
2	Do you have difficulty moving your jaw to the sides?
3	Do you feel fatigue or muscle pain when you chew?
4	Do you have frequent headaches?
5	Do you have neck pain or a stiff neck?
6	Do you have ear aches or pain in that area (TMJ)?
7	Have you ever noticed any noise in your TMJ while chewing or opening your mouth?
8	Do you have any habits such as clenching or grinding your teeth?
9	Do you feel that your teeth do not come together well?
10	Do you consider yourself a tense (nervous) person?

Absolute skin temperatures over the masticatory muscles and TMJ were determined bilaterally, and asymmetry was evaluated by subtracting the temperature of one side from that of the other side. Three images were captured for each volunteer and the mean value was used in the statistical analysis.

2.8. Statistical analysis

The Shapiro–Wilk test was used to determine the normality of the data. The Kruskal–Wallis test, followed by Dunn's test, was used for comparisons among groups according to TMD severity. Spearman's correlation coefficients were calculated to determine the strength of associations among variables. Interpretation of the coefficients was based on the classification proposed by Munro (2001): weak (0.26–0.49), moderate (0.50–0.69), strong (0.70–0.89), and very strong (0.90–1.00). The level of significance was set to 5% ($p < 0.05$) for all analyses. Data processing was performed with the aid of BioEstat software (version 5.3; Mamirauá Institute, Belém, PA, Brazil).

3. Results

The application of these criteria led to the loss of 10 volunteers, seven of whom had BMIs above the established limit and three of whom were currently receiving orthodontic treatment. Thus, the final sample comprised 60 women.

Table 2 displays the comparisons of demographic and clinical characteristics between groups. Thus, as was already expected, significant differences in the FAI score was observed in all comparisons ($p < 0.01$).

Table 3 displays correlations between TMD severity and infrared thermography findings for the masticatory muscles and TMJ. Weak, positive, and significant associations were found between FAI score and skin temperature over the left TMJ ($rs = 0.195$, $p = 0.009$) and right TMJ ($rs = 0.238$, $p = 0.001$).

Table 4 displays the skin temperatures over the masticatory muscles and TMJ among groups defined according to TMD severity. Significantly higher skin temperatures over the right and left TMJ were found in groups with more severe TMD ($p < 0.05$).

4. Discussion

The present findings reveal associations between the severity of TMD, classified using the FAI, and skin temperatures over the right and left TMJ. Moreover, the comparisons demonstrated a greater increase in skin temperatures over the right and left TMJ in groups with more severe TMD.

Table 3 Correlations between skin temperature and score on the Fonseca anamnestic index (FAI).

Correlation	*rs*	*p* value
LM (°C) × FAI (score)	−0.001	0.983
RM (°C) × FAI (score)	0.072	0.337
AM (°C) × FAI (score)	−0.118	0.115
LT (°C) × FAI (score)	−0.113	0.133
RT (°C) × FAI (score)	0.010	0.888
AT (°C) × FAI (score)	−0.103	0.171
LTMJ (°C) × FAI (score)	0.195	0.009*
RTMJ (°C) × FAI (score)	0.238	0.001*
ATMJ (°C) × FAI (score)	−0.120	0.110

LM: left masseter; RM: right masseter; AM: thermal asymmetry between masseter muscles; LT: left anterior temporalis muscle; RT: right anterior temporalis muscle; AT: thermal asymmetry between anterior temporalis muscles; LTMJ: left temporomandibular joint; RTMJ: right temporomandibular joint; ATMJ: thermal asymmetry between temporomandibular joints.

* Statistically significant ($p < 0.05$).

Although the relationship between TMD severity and skin temperature has not been established in the literature, studies published to date have shown that skin temperature over the joint is higher in individuals with TMJ conditions, such as arthralgia, osteoarthritis, or osteoarthrosis, than in healthy individuals (Gratt et al., 1994b; Pogrel et al., 1989; Rodrigues-Bigaton et al., 2013). However, contrary to the present findings, several authors have reported greater thermal asymmetry in individuals with TMD than in those without this disorder (Gratt and Anbar, 1998; Gratt and Sickles, 1993; Gratt et al., 1994a; McBeth and Gratt, 1996). This divergence may be explained by differences in sample size. In the present study, the sample size was calculated based on the absolute temperature over the TMJ.

According to Anbar and Gratt (1998), a possible physiopathological explanation for the increase in skin temperature over the TMJ in individuals with TMD is hyperthermia induced by regional vasodilatation, conditioned by nitric oxide produced in the extravascular space of the joint. Arinci et al. (2005) investigated the relationships between mediators of pain, inflammation, and tissue damage and alterations in the TMJ and found an association between the severity of the disorder and levels of these mediators in the synovial fluid of the TMJ.

No association was found between TMD severity and skin temperature over the masseter or anterior temporalis muscle in

Table 2 Comparison of the variables age, body mass index (BMI) and Fonseca anamnestic index (FAI) score according to the TMD severity.

Variable	Without TMD ($n = 15$)	Mild TMD ($n = 15$)	Moderate TMD ($n = 15$)	Severe TMD ($n = 15$)
Age (years)	21.83 (3.18)	21.13 (1.95)	23.06 (4.14)	24.80 (5.00)
BMI (kg/m^2)	21.13 (1.86)	21.81 (1.91)	22.63 (2.03)	21.11 (2.04)
FAI (score)	9.00 (5.07)[a,b,c]	31.00 (6.03)[d,e]	57.66 (6.51)[f]	77.66 (6.77)

Values shown in mean (standard deviation).

[a] Differs from group with mild TMD ($p < 0.01$, ANOVA one-way and Tukey's post hoc test).
[b] Differs from group with moderate TMD ($p < 0.01$, ANOVA one-way and Tukey's post hoc test).
[c] Differs from group with severe TMD ($p < 0.01$, ANOVA one-way and Tukey's post hoc test).
[d] Differs from group with moderate TMD ($p < 0.01$, ANOVA one-way and Tukey's post hoc test).
[e] Differs from group with severe TMD ($p < 0.01$, ANOVA one-way and Tukey's post hoc test).
[f] Differs from the group with severe TMD ($p < 0.01$, ANOVA one-way and Tukey's post hoc test).

Table 4 Comparison of skin temperature (°C) according to degree of severity of temporomandibular disorder (TMD).

Region	Fonseca anamnestic index			
	Without TMD	Mild TMD	Moderate TMD	Severe TMD
LM	32.75 (32.32–33.30)	32.40 (32.10–33.40)	32.90 (32.10–33.50)	33.40 (31.60–33.90)
RM	32.55 (32.02–33.00)	32.40 (31.90–33.00)	33.20 (32.20–33.70)	33.00 (31.90–33.90)
AM	0.40 (0.20–0.60)	0.30 (0.20–0.60)	0.20 (0.20–0.50)	0.30 (0.10–0.50)
LT	34.50 (34.10–34.90)	34.30 (34.00–34.60)	34.20 (33.90–34.60)	34.50 (33.10–35.00)
RT	34.00 (33.70–34.77)	33.90 (33.60–34.70)	34.40 (33.80–34.60)	34.10 (33.40–35.50)
AT	0.30 (0.20–0.60)	0.30 (0.12–0.50)	0.40 (0.20–0.60)	0.40 (0.10–0.70)
LTMJ	33.45[a] (32.90–34.40)	33.30[b] (32.80–34.00)	33.90 (33.00–34.30)	34.40 (33.40–34.90)
RTMJ	33.45 (33.10–33.80)	33.30[c,d] (32.80–33.90)	34.00 (33.60–34.50)	34.20 (33.10–34.90)
ATMJ	0.40 (0.30–0.60)	0.30 (0.10–0.40)	0.30 (0.20–0.60)	0.30 (0.10–0.50)

Data expressed as median (first–third quartile). LM: left masseter; RM: right masseter; AM: thermal asymmetry between masseter muscles; LT: left anterior temporalis muscle; RT: right anterior temporalis muscle; AT: thermal asymmetry between anterior temporalis muscles; LTMJ: left temporomandibular joint; RTMJ: right temporomandibular joint; ATMJ: thermal asymmetry between temporomandibular joints.
[a] Differs from group with severe TMD ($p < 0.05$, Kruskal–Wallis test and Dunn's post hoc test).
[b] Differs from group with severe TMD ($p < 0.05$, Kruskal–Wallis test and Dunn's post hoc test).
[c] Differs from group with moderate TMD ($p < 0.05$, Kruskal–Wallis test and Dunn's post hoc test).
[d] Differs from group with severe TMD ($p < 0.05$, Kruskal–Wallis test and Dunn's post hoc test).

the present study. The literature contains divergent findings regarding the behavior of skin temperature over the masticatory muscles in individuals with TMD. In comparison with control groups, Pogrel et al. (1989) and Nemcovsky et al. (1995) found increased skin temperature in affected individuals, whereas Gratt et al. (1994a) and Rodrigues-Bigaton et al. (2014) found reduced temperature and Dibai Filho et al. (2013) found no difference. Thus, specific studies of the metabolic and vascular aspects of the muscle component of TMD are needed.

With regard to clinical implications, the present findings underscore the importance of considering the joint aspect in individuals with more severe TMD. Several therapeutic modalities, such as laser therapy (Fikáčková et al., 2006), pulsed radio frequency energy therapy (Al-Badawi et al., 2004) and splint therapy (Madani and Mirmortazavi, 2011), may be employed for such patients to reduce pain and inflammation in the TMJ. Moreover, the use of different assessment tools is important to more completely evaluate diverse aspects of TMD, such as skin temperature, severity, muscle activity, and range of motion.

The recruitment of female volunteers from the university community is a limitation of the present study. Further studies with larger samples and volunteers recruited from tertiary care centers are needed to ensure the inclusion of subjects with profiles similar to those of patients who seek clinical treatment. Furthermore, men should be included in study samples, given sex-based differences in skin temperature in certain areas of the body (Marins et al., 2014).

5. Conclusion

The present findings demonstrate an association between FAI score and skin temperature over the TMJ, as determined using infrared thermography. Women with more severe TMD exhibited increased temperatures over the right and left TMJ.

Conflict of interest

The authors have no conflict of interest to declare.

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