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Original article

Is scoliosis related to mastication muscle asymmetry and temporomandibular disorders? A cross-sectional study

İlyas Uçar [a,*], Sabri Batın [b], Mustafa Arık [c], Ahmet Payas [d], Erdal Kurtoğlu [a], Caner Karartı [e], Turgut Seber [f], Serap Bulut Çöbden [g], Hande Taşdemir [a], Erdoğan Unur [a]

[a] Erciyes University, Faculty of Medicine, Department of Anatomy, Turkey
[b] Kayseri Training and Research Hospital, Department of Orthopaedics and Traumatology, Turkey
[c] Pınarbaşı State Hospital, Department of Orthopaedics and Traumatology, Turkey
[d] Hitit University, Sungurlu Vocational School, Department of Therapy and Rehabilitation, Turkey
[e] Kırşehir Ahi Evran University, Department of Physiotherapy and Rehabilitation, Turkey
[f] Kayseri Training and Research Hospital, Department of Pediatric Radiology, Turkey
[g] Kayseri Training and Research Hospital, Department of Otolaryngology, Turkey

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ABSTRACT

Objective: Patients with adolescent idiopathic scoliosis (AIS) may face motor control problems and health disability barriers during mandibular movements and chewing. However, studies investigating the extent of these disadvantages, and possible associated factors are quite limited in patients with AIS. This study was conducted to gain a deeper perspective on the effect of AIS on temporomandibular disorders (TMD) and to contribute to the small amount of data on this subject.
Methods: Twenty-nine patients with AIS and 29 age- and sex-matched asymptomatic controls participated in this cross-sectional study. Cobb's method was used to measure scoliosis curves. In both groups, the volume of the masseter muscle was determined on magnetic resonance imaging, and Helkimo and Fonseca anamnestic indexes were used to evaluate temporomandibular joint (TMJ).
Results: It was observed that the TMD symptoms were higher in the AIS group (22.6- Helkimo and 1.2 - Fonseca) than the asymptomatic group (13.6 - Helkimo and 0.7 - Fonseca). There was no significant asymmetry in masseter volume in patients with AIS, however the volume of the masseter muscles was smaller in the AIS group (R = 14.6/L = 13.6) compared to the control group (R = 16.1/L = 16.2).
Conclusions: The study results indicate that spinal curvatures affect the anatomical, biomechanical, and kinesiological features of the masticatory system, and individuals with AIS may experience more chewing problems than asymptomatic individuals. Examining musculoskeletal properties of masticatory system can provide information about the limitation of the TMJ in patients with AIS.

1. Introduction

Adolescent Idiopathic Scoliosis (AIS) is a common spinal deformity that occurs in childhood and progresses during adolescence; however, the exact etiology remains highly unknown (Weinstein and Buckwalter, 1994). Recent studies suggest that there is a relationship between scoliosis and mandibular deviation (Nakashima et al., 2017). Temporomandibular disorders (TMD) are defined as a class of musculoskeletal disorders involving the temporomandibular joint (TMJ), masticatory muscles, and associated structures. Due to lack of a consensus, studies on the etiology, diagnosis, and treatment of TMD are ongoing (Kandasamy and Greene, 2020). The possible relationship between AIS-related postural changes and TMD needs further investigation. The American Academy of Orofacial Pain and studies investigating the effect of spinal deformities on TMD indicate that there may be a link between cervical spine disorders and TMD (Benliet et al., 2018). However, objective evidence on the subject is yet insufficient (Nakashima et al., 2017). Contrary to these opinions, in the literature some researchers reported that TMD are not often related with head and body posture (Manfredini et al., 2012).

Imaging of the TMJ has evolved considerably parallel with the development of new Technologies. Magnetic Resonance Imaging (MRI)

* Corresponding author.
E-mail address: ilyas.ucar@erciyes.edu.tr (İ. Uçar).

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is one of the common imaging modalities for the evaluation of TMJ due to its high resolution, clear contrast between tissues needless of ionizing radiation or contrast agent (Bag et al., 2014). Ultrasonography (USG) is reported as a cost- and time-saving alternative modality for the evaluation of TMJ (Thirunavukarasu et al., 2021). The use of USG is identified in the fields of masticatory muscles, tongue and swallowing, temporomandibular joint, soft tissue thickness, periodontal changes during orthodontic tooth movement, and tooth movement (Orhan and Görürgöz, 2021).

Postural changes may lead to adaptations in head and neck muscles, and structures related to stomatognathic system such as masticatory muscles, ligaments, and TMJ (Nakashima et al., 2017, 2018; Benli and Gokcen-Rohlig, 2018). Previous studies show that examining the anatomical structures of the musculoskeletal system can provide information regarding the stability limitations in these patients (Uçar et al., 2021). In this context, the present study aimed to objectively investigate the possible association between AIS and TMD. To serve this purpose, TMJ evaluations and masseter muscle volume calculations were carried out on individuals with AIS and asymptomatic volunteers.

2. Materials and methods

2.1. Participants and study groups

The orthopedic surgeon (BS) of the Kayseri City Hospital, Orthopedics Department referred individuals who were diagnosed with AIS and had surgical indications to participate in the study. The purpose and scope of the study was explained to the participants in detail, and informed consent forms were signed by their parents. The study was approved by the Kayseri City Hospital Clinical Research Ethics Committee (Registration date/no: September 09, 2021/476), and conducted in accordance with the principles of the Declaration of Helsinki.

AIS group (n = 29): Participants diagnosed with AIS by a specialist orthopedist (BS) in Kayseri City Hospital, Orthopedics Department.

Inclusion criteria: Being diagnosed with right thoracic AIS, having a Cobb angle above 40° and an indication for surgery (Little and Adam, 2012), being in the age range of 10–18 years, and being female.

Exclusion criteria: Having a history of trauma or surgery affecting the head-neck and spine, being diagnosed with TMD, history of orthodontic treatment, using dental braces or bite plates, using any orthoses or corsets for cervical spine and/or mandibula, and having neuromuscular diseases.

Control group (n = 29): Asymptomatic participants were qualified by the same orthopedic surgeon, who excluded any signs of musculoskeletal pathologies by physical examination. The presence of spinal curvatures was checked with a scoliometer.

Inclusion criteria: Being female, absence of a history of trauma or surgery affecting the head-neck and spine, absence of a previous TMD diagnosis or orthodontic treatment, not using braces or bite plates, and absence of neuromuscular diseases.

Age, weight, and height of the participants were recorded. The Body Mass Index (BMI) was calculated for each participant using the formula [BMI = Weight/Height x Height (kg/m2)].

2.2. Definition of vertebral lateral deviation using cobb angle

For each participant, the degree of curvature in the frontal plane was measured by two orthopedists (BS and AM) and a radiologist (ST). The coronal plane view of radiographs was used to measure the 'Cobb' angle, which is the angle between the upper border of the superior vertebra and the lower border of the inferior vertebra of the spinal curve. For each participant, the mean of the three measurements was recorded as the Cobb angle (Fig. 1).

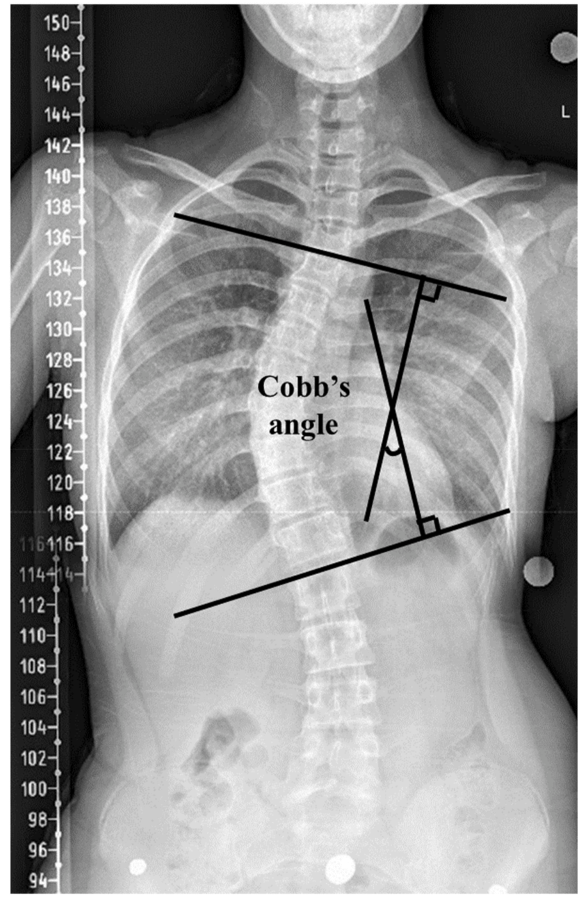

Fig. 1. Measurement of spinal curvature using with Cobb's angle.

2.3. TMJ evaluation

TMJ evaluations were done by two physiotherapists with at least 10 years experience on musculoskeletal disorders (UI and PA) under the supervision of an otolaryngologist (CSB).

2.3.1. Helkimo anamnestic index (HAI)

Initially developed for an epidemiological study, the HAI is a standard form used in the evaluation of TMD (Leamari et al., 2019). It is the first index for the assessment of TMJ pain and dysfunction (Helkimo, 1974). The clinical index of dysfunction is obtained based on the clinical examination and comprises the following classes:

I. Muscle pain during palpation: No tenderness to palpation in the masticatory muscles = 0, tenderness to palpation at 1–3 sites = 1, and tenderness to palpation at 4 or more sites = 5.
II. TMJ pain during palpation: No tenderness to palpation = 0, tenderness to palpation laterally = 1, and tenderness to palpation posteriorly = 5.
III. Pain upon movement of the mandibula: No pain on movement = 0, pain on one movement = 1, and pain on two or more movements = 5.
IV. Impaired TMJ function: Smooth movements without TMJ sounds and less than 2 mm deviation during opening or closing movements = 0, TMJ sounds in one or both joints and/or deviation more than 2 mm = 1, and locking and/or luxation of the TMJ = 5.
V. Impaired range of movement/mobility: Normal = 0, slightly impaired = 1, and severely impaired = 5.

All sub-scores are summed to obtain a total score. The dysfunction index (DI) is defined as: Clinically Asymptomatic (total score = 0), Mild Dysfunction (total score = 1–4), Moderate Dysfunction (total score = 5–9), and Severe Dysfunction (total score = 10–25).

In this study, the HAI was performed by an experienced physiotherapist (UI) who was blind to the group allocations.

2.3.2. Fonseca anamnestic index (FAI)

The FAI was initially developed to assess the severity of TMD based on signs and symptoms. This index comprises ten questions with three response options: "yes" (10 points), "sometimes" (5 points) and "no" (0 points). The total score is the sum of the scores in each item and the classification is defined as (dos Santos Berni et al., 2015):

The total score is the sum of all item scores in each item and is categorised as (dos Santos Berni et al., 2015): No TMD (total score = 0–15), Mild TMD (total score = 20–40), Moderate TMD (total score = 45–65), and Severe TMD (total score = 70–100).

The FAI was performed by an experienced physiotherapist (PA) who was blind to the group allocations.

2.4. Cranial MRI and masseter muscle volume

Cranial MRI was performed using a 3T Siemens Skyra scanner (Siemens, Germany). Anatomical images were acquired in sagittal plane using T1-weighted 3D Magnetization Prepared Rapid Gradient Echo (MPRAGE) sequence, with the following parameter settings: TR/TE = 2300/3.4 ms, flip angle = 9°, acquisition matrix = 256 × 256, FOV = 250 × 250 mm^2, number of slices = 172, and slice thickness = 1.0 mm.

MRIs with a section thickness of 0.1 mm were recorded in JPEG format to calculate the volume of the masseter muscle. All these images were displayed simultaneously in the "ImageJ" program, which can be downloaded from the web address of: https://imagej.nih.gov/ij/download.html. An image series was created by selecting "stack→image to stack" icon under the "image" tab of the ImageJ program. Using the options in the "measurement and tools" tab on the RadiAnt program, the length of any specific spot on the image was measured. In the ImageJ program, the same spot was marked in the same section using the "straight" button. The images were calibrated using "Set Calibrate" option under the "analyze" tab of the ImageJ program. In the next step, the boundaries of the masseter muscle were determined manually by using the "Free Hand" button of the ImageJ program so that the area can be measured from each section where the masseter muscle is located. The cross-sectional surface area was recorded in an ImageJ tab with the "M" key. The volume was obtained by multiplying the sum of the area values of each section with the section thickness (Fig. 2). The entire procedure was repeated bilaterally on the MRIs of each participant for right and left masseter muscle. Volume measurements were calculated separately by a radiologist (ST) and two anatomists (UI and KE), and the mean of the three values was used in the statistical analysis.

2.5. Statistical analysis

The data were evaluated using the Statistical Package for the Social Sciences 22.0 program for Windows. The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov-Simirnov/Shapiro-Wilk's test) to check normality. We used descriptive statistics and reported counts and proportions for categorical data and measures of distribution for continuous data. An independent *t*-test or χ2 test was performed to compare the baseline characteristics. To evaluate the changes in the volume of masseter muscle on the MRI, a 2*2 [group (participants with- and without adolescent idiopathic scoliosis) * side (right or left)] repeated measures ANCOVA was performed with group as a between-groups factor and side as a within-subjects factor, and with demographical measures set as the covariates. When the F-ratio was significant, Bonferroni's post hoc test was applied to identify the mean differences. Effect sizes were determined as partial eta squared (η2p). Also, the stepwise multiple linear regression analysis was used to determine the variables that had the greatest influence on the mean difference in the volume of the masseter muscles between the two sides in participants with AIS. Before the regression analysis, Pearson product-moment correlation coefficients were used to examine the correlations between mean difference in the volume of the masseter muscles between the two sides and other variables (age, body mass index, Cobb angle, Risser sign, Fonseca Anamnestic Index scores, Helkimo Clinical Dysfunction Index scores). The correlation coefficients >0.5 were considered as a strong correlation, 0.3 to 0.5 as a moderate correlation and 0.2 to 0.3 as a weak correlation. Significantly correlated variables with the mean difference in the volume of the masseter muscles between the two sides were included in the regression model. Cook's Distance and Centered Leverage Value were used to identify and treat outliers. The level of significance was set at $p < .05$.

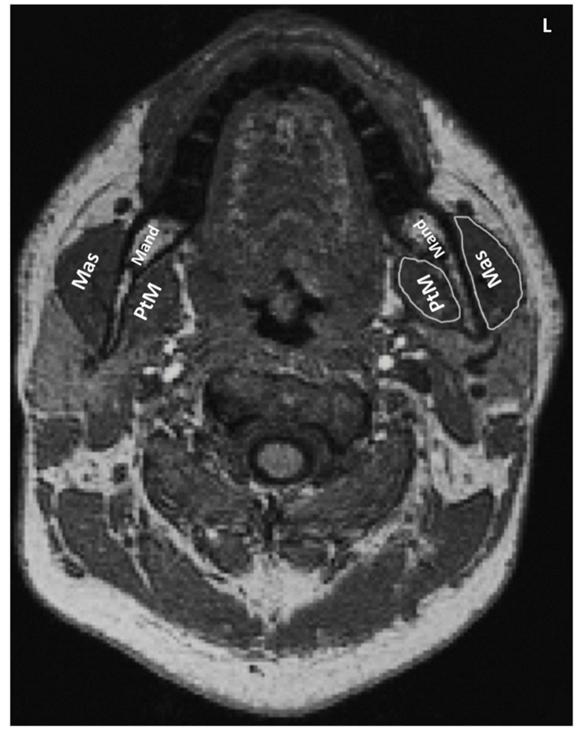

Fig. 2. Measurement of masseter muscle
An axial T1 image at alveolar arch level. **Mas**: Masseter muscle **Mand**: Mandible, **PtM**: Medial pterygoid muscle.

3. Results

A total of 58 participants with (n = 29) and without adolescent idiopathic scoliosis (n = 29) with a severe thoracic curve magnitude (Cobb = 41°–50°) were included in the study. Descriptive characteristics of the participants are presented in Table 1. There was no significant difference between the two groups in terms of baseline characteristics ($p>.05$).

The ANCOVA revealed a significant group*side interaction effect regarding masseter muscle volume [($p = .020$; η2p = .179)] in terms of two groups (Table 2). The volume of masseter was smaller in the AIS group compared to the asymptomatic participants. In addition, Fonseca Anamnestic Index scores and Helkimo Clinical Dysfunction Index scores were higher in the AIS group ($p < .001$).

There was a significant correlation between the mean difference in the volume of the masseter muscles between the two sides in participants with AIS and Cobb angle ($r = 0.248$, $p = .043$), Fonseca Anamnestic Index scores ($r = 0.642$, p=<.001) and the Helkimo Clinical Dysfunction Index scores ($r = 0.593$, $p = .001$) (Table 2). These variables

Table 1
Descriptive statistics of the participants.

Variable	Participants with AIS	Asymptomatic participants	p
Age	14.7 ± 1.9	14.9 ± 2.0	.95
Body mass index (kg/m^2)	20.4 ± 1.3	20.0 ± 2.1	.78
Female (%)	29 (100%)	29 (100%)	1.00
Cobb angle	46.6 ± 4.4	–	–
Risser sign	1.7 ± 1.4	1.7 ± 1.3	.63
Lenke curve type 1	29 (100%)	–	–
Dominant side upper (R)	29 (100%)	29 (100%)	1.00
Dominant side lower (R)	29 (100%)	29 (100%)	1.00

Independent samples *t*-test or $\chi 2$ test; R: Right; AIS: Adolescent idiopathic scoliosis.

were included as independent variables in the regression model to determine possible factors of the mean difference in the volume of the masseter muscles. However, the stepwise multiple regression analysis demonstrated that there were no significant and independent factors of the mean difference in the volume of the masseter muscles between the two sides in participants with AIS (p>.05).

4. Discussion

To the best of our knowledge, there is no study investigating the morphology of the masticatory muscles in individuals with scoliosis to demonstrate potential asymmetry in the soft tissue. In this study, we evaluated the TMJ and the masseter muscle size in individuals with AIS and compared it with asymptomatic individuals to gain a deeper perspective on the effect of AIS on the mastication structures. To minimize the gender and hormonal differences, only female participants were included in the study. In addition, only individuals with right thoracic scoliosis were included in the AIS group, and the BMIs of the two groups were similar. Our results indicated that the masseter volume was smaller, and the HAI and FAI scores were higher in the AIS group compared to the control group. Also, there was a significant relationship between the mean difference in right and left masseter muscle volumes and the Cobb angle, FAI, and HAI scores in the AIS group.

Scoliosis is an orthopedic condition that involves progressive lateral deviation of the spine and is characterized by defective posture and is more common in girls (Nakashima et al., 2017). AIS is the most common form of spinal deformity with unknown etiology affecting adolescents (Pérez-Machado et al., 2020). Pecina et al. suggested a relationship between scoliosis and TMD, showing a higher frequency of hereditary orthodontic anomalies in 202 patients aged 7–17 years treated for idiopathic scoliosis (Pećina et al., 1991). Nakashima et al. reported a positive correlation between Cobb angle and the degree of mandibular deviation (Nakashima et al., 2017). Another study reported that 23 (27.1%) of 85 patients with jaw deformity had scoliosis (Ikemitsu et al., 2006). Therefore, investigating the possible effects of posture on TMJ and occlusion remains an ongoing subject in the orthodontic literature.

In the present study, to evaluate the TMJ in individuals with and without AIS, we used the FAI, as a sensitive screening tool to identify patients with TMD (Stasiak et al., 2020), and the HAI, which can discriminate between individuals with and without TMD (Alonso-Royo et al., 2021). The results showed that individuals with AIS had higher HAI and FAI scores than asymptomatic participants, indicating a relationship between scoliosis and TMD. Previous studies have introduced two classifications for scoliosis associated with jaw deformities: (1) changes in bony structures, and (2) muscle imbalance due to spinal curvature (Kondo, 2004; Lee and Yu, 2012). In our study, we observed a positive correlation between the volumetric differences of the right-left masseter muscles and the scoliosis angle values, and HAI and FAI scores in individuals with AIS. It can be assumed that the impaired biomechanical and neuromuscular balance due to spinal curvature and muscle asymmetry in individuals with AIS can worsen TMD symptoms. Ikemitsu et al. reported a relationship between jaw deformities and scoliosis in their study on cephalometric radiography and chest x-rays (Ikemitsu et al., 2006). Based on these data, it seems that changes in bone structure and muscle imbalance due to spinal curvature are involved in the scoliosis-TMD relationship.

The position of the mandibula, which plays a key role in the functionality of the TMJ, is maintained by anti-gravity muscle activity and various neurophysiological and anatomical mechanisms. The masseter and pterygoid muscles form a mandibula suspending structure known as "pterygomasseteric sling" (Thomas and Yaremchuk, 2009). Due to its superficial localization, the masseter muscle can be easily palpated and evaluated in physical examination. The size of the mastication muscles varies according to the craniofacial morphology and is an important indicator of the functional capacity of the masticatory system (Boom et al., 2008; Naser-Ud-Din et al., 2011). Changes in muscle size are considered as important factors in determining occlusal contact area, teeth, muscle and TMJ sensitivity and occlusal strength (Ellis et al., 1996). We measured masseter muscle volumes using the cranial MR images of the participants and concluded that the muscle volume was smaller in the AIS group compared to the control group. van Spronsen et al. reported a correlation between the cross-sectional area of the masseter muscle and the maximum voluntary biting force and considered it as an indicator of the functional capacity of the masticatory system (van Spronsen et al., 1991). However, there was no statistically significant difference in the volume values of the right and left masseter muscles in the AIS group. Nevertheless, while the right-left masseter muscle volumes were almost similar in the control group (R = 16.1 ± 2.9, L = 16.2 ± 2.5), the right masseter muscle was larger in volume in the AIS group (R = 14.6 ± 2.6, L = 13.6 ± 2.8). Further detailed studies regarding the nutrition and chewing habits of the participants are needed on what causes this situation.

5. Limitations

Limitations of our study include the small sample size and lack of physical examination. The orientation of muscle fibers is related to skeletal morphology. Present study is that the muscle fiber orientation was not studied. Muscle size is used to determine muscle function, whereas including other parameters such as bite force and electromyography analyses could yield to more precise results regarding muscle

Table 2
Comparison of masseter muscle volume and clinical characteristics between two groups.

	Participants with AIS (n = 29)			Asymptomatic participants (n = 29)			2 × 2 ANCOVA	
	Right	Left	p[1]	Right	Left	p[1]	Side p[2] (η^2p)	Group*Side p[2] (η^2p)
Masseter muscle volume (cm^3)	14.6 ± 2.6	13.6 ± 2.8	.180	16.1 ± 2.9	16.2 ± 2.5	.896	.049 (.131)*	.020 (.179)*
Clinical characteristics							p[1]	
Fonseca Anamnestic Index	22.6 ± 8.3			13.6 ± 7.1			<.001*	
Helkimo Clinical Dysfunction Index	1.2 ± 0.9			0.7 ± 0.7			.013*	

AIS: Adolescent idiopathic scoliosis; p[1]: Independent samples *t*-test results for within-group side comparisons; p[2]: two-way repeated measures analysis of covariance with a mixed model. Figures in parentheses are effect sizes partial eta squared (η^2p).

function. Also, it was not stated how long the participants were followed up with the diagnosis of AIS.

6. Conclusion

The masseter muscle can be easily evaluated by palpation and via imaging methods. Spinal curvatures are closely related to TMD, and individuals with AIS may encounter more chewing problems than asymptomatic individuals. No significant asymmetry was detected in the masseter volume in patients with AIS. However, it was observed that they had smaller muscle volume. It seems that changes in spine biomechanics may lead to anatomical, biomechanical, and kinesiological changes in mastication components. Therefore, individuals with AIS are recommended to be routinely checked for TMD, and those with TMD need routine spinal evaluations. In addition, the size of the masseter muscle can provide an idea for determining the functionality and limitations of the jaw in both scoliotic and asymptomatic individuals.

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An institutional ethics approval statement

This study was approved by Kayseri City Hospital Clinical Research Ethics Committee (Registration date/no: August 09, 2021/476).

Declaration of competing interest

The authors have no conflicts of interest to declare.

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