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Facial - Neck - Shoulder Asymmetry Profile in Adolescent Idiopathic Scoliosis with Main or Double Thoracic Curve

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ABSTRACT

Purpose: Scoliosis is a three-dimensional spinal deformity that induces asymmetries in the body. Existing literature primarily focuses on asymmetry caused by scoliosis, particularly in the shoulders, waistline, breasts, and pelvis. This study aimed to compare the symmetrical profiles of adolescents with idiopathic scoliosis and healthy peers in the facial, neck, and shoulder areas using two-dimensional photographic methods.

Method: Thirty-one adolescents diagnosed with Adolescent idiopathic scoliosis (AIS) and 31 healthy controls participated in the study. Facial, neck, and shoulder asymmetry were evaluated in 2D photogrammetry. Active mandibular movements were measured with a ruler, while neck mobility was assessed using a standard flexible tape. Axial cervical rotation was measured with a scoliometer.

Results: The findings revealed that participants with AIS showed significantly greater eye ($p < 0.001$), middle face ($p < 0.001$), and mouth ($p = 0.010$) asymmetry compared to the control group. Additionally, individuals with scoliosis displayed significant asymmetry in the right-to-left trapezium angle ratio, as well as noticeable differences in shoulder and axillary heights.

Discussion: The results suggest that scoliosis-related asymmetries are not confined to the trunk but also affect the head, neck, and shoulder regions.

Key Words: Spine, Scoliosis, Asymmetry, Facial, Cosmesis.

INTRODUCTION

Adolescent Idiopathic Scoliosis (AIS) is a spinal disorder that typically emerges during childhood and tends to progress throughout adolescence. Although its cause remains unidentified, AIS affects spinal alignment in all three anatomical planes —sagittal, coronal, and axial— resulting in noticeable postural deviations that may involve the neck, shoulders, thorax, trunk, and pelvis. Structural changes caused by scoliosis often result in noticeable postural deformities, including shoulder asymmetry, an uneven waistline, visible rib prominence, and lateral shift in the trunk (1).

The foremost clinical concern for patients with AIS is centered on the aesthetic impact resulting from the spinal deformity. Besides cases of severe scoliosis that come with complications affecting quality of life and respiratory impairment, individuals with AIS often suffer from characteristic features such as shoulder imbalance, waistline asymmetry, rib hump, and pelvic misalignment (2). A significant number of individuals seeking medical attention from specialists or clinics for scoliosis-related complaints have done so primarily due to shoulder asymmetry (3). Similarly, according to the results of a previous study, individuals with scoliosis and their families are most concerned about waist asymmetry and rib hump in terms of cosmetic appearance (4).

These postural changes can extend their impact beyond the spinal column, causing adjustments within the head and neck musculature, as well as adaptations in structures associated with the stomatognathic system, including masticatory muscles, ligaments, and the mandibular joints (5). Recent studies on the stomatognathic system in patients with idiopathic scoliosis have mostly involved cross-sectional designs focusing on its functional and structural impairments. A hypothesis linking abnormal body posture to various craniofacial orthopedic and orthodontic conditions has been proposed, with most studies relying on anteroposterior radiographs and frontal cephalograms for evaluation (6). These findings suggest that postural misalignment may have an impact on craniofacial structure and function. However, research has not extensively examined the assessment of facial, neck, and shoulder asymmetries in terms of soft mobility and photographic assessment. This study focuses on investigating the effects of scoliosis on the face, neck, and shoulder through a photographic evaluation. The findings are anticipated to enhance the understanding of the broader cosmetic and functional implications of AIS.

METHODS

Participants and Study Protocols

The study involved 31 adolescent girls with idiopathic scoliosis and 31 healthy controls. The research was conducted between December 2020 and February 2022 following ethical approval from the University Non-Interventional Clinical Research Ethics Committee (GO20/694, August 2020). Informed consent was obtained from all participants and/or their families. The scoliosis group comprised untreated female patients aged 10-18 with scoliosis greater than a Cobb's angle of 15° (7), excluding patients with congenital scoliosis, spinal deformities, prior spine surgery, tumors, or those unwilling or unable to participate. The control group consisted of age-matched girls with no recent orthopedic, neurologic, or other related medical conditions who already had a thoracic x-ray and no scoliosis detected. In addition, participants who had undergone dental treatments such as facial surgery, root canal therapy, dental implants, endodontic and orthodontic procedures, and other invasive dental procedures, as well as facial interventions such as Botox or lip augmentation, were excluded from both groups. Participants in all groups underwent evaluation by a physician and were subsequently included in their respective groups.

Examination Procedure

Participants' age, height, weight, and Body Mass Index (BMI) were documented as part of their demographic data. The degree of scoliosis was recorded based on the evaluation of the physician who previously diagnosed the patients. The curve pattern was classified based on the Scoliosis Research Society classification, taking into account the apex location, and included only main and primary thoracic double major curves.

A. Photographic Assessments

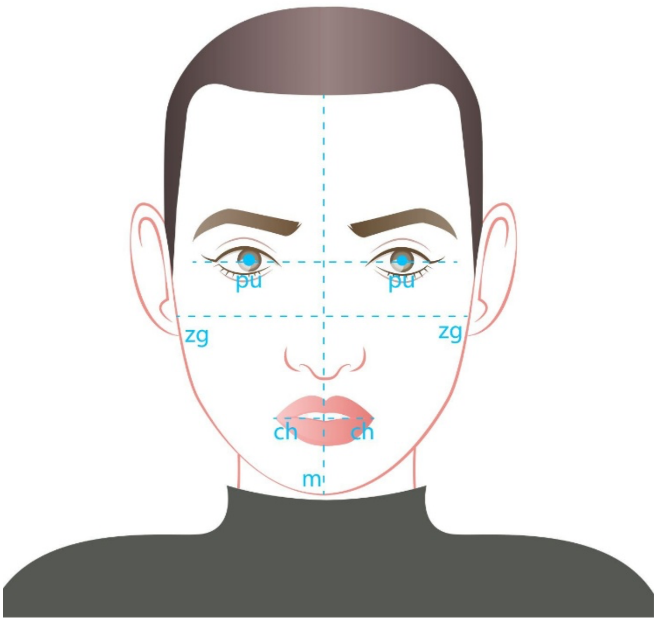

Figure 1. Measurement taken from six anthropometric landmarks on the profile(s) and front view of the face. Abbreviations; pu: pupil, zg: zygomaticus, ch: cheilion. The measured distances are as follows: zg-zg, middle face width; pu-pu, biocular width; ch-ch, mouth width; m, face height reference line.

A digital camera was mounted on a tripod at 110 cm height, and 100 cm was used to capture standardized anterior-view photographs. Standing positions were guided by a marked floor cross, and patients were instructed to adopt a relaxed posture. Glasses were removed, and long hair was tied up. Photos were taken from the front with a 2 cm × 2 cm white square sticker on the forehead and both cheeks, facilitating centimeter-based measurements instead of pixels. The camera lens was positioned perpendicular to the square sticker, aiding precise measurements using the Image J program (8).

For each participant, two areas have been evaluated photographically.

1. Facial asymmetry: Six facial landmarks were identified using image analysis software (Figure 1), based on reference points that have been reported in the literature as valid and reliable for 2D facial asymmetry assessment (9). These included the pupil, zygomaticus, and cheilion. Distances from these landmarks to the facial height reference line (m) were used to calculate asymmetry. Specifically, biocular width (between the pupils), middle face width (between the zygomatic points), and mouth width (between the cheilion points) were measured from the frontal facial view (10,11).

A face-specific symmetry/asymmetry value, called as “asymmetry index”, was calculated from the acquired anthropometric facial data, and the face was divided into three regions based on the sagittal and frontal photographs: 1) Eye asymmetry, 2) Middle face asymmetry, 3) Mouth asymmetry. The perfectly symmetric face takes the value zero. Higher scores indicate higher asymmetry. The formula is as follows (12).

Asymmetry index = | (Right - Left) / (Right + Left) | x 100 (%)

2. Neck asymmetry and shoulder asymmetry: To evaluate neck and shoulder asymmetry, Left/Right Trapezium Angle and Shoulder and Axilla Height Difference Angles were used. These methods are commonly applied in postural assessments and have been reported as reliable and consistent when used in 2D photographic analysis (13).

Left/right trapezium angle (LRTA): The trapezium angle is characterized as the angle formed between the line tracing the outer border of the trapezius muscle and the horizontal axis. The ratio of this angle for the left and right sides was employed for statistical analysis.

Shoulder height difference angle (SHDA): A line drawn between the superior borders of the bilateral acromion processes and aligned with the horizontal axis creates this angle.

Axilla height difference angle (AHDA): The angle formed by the horizontal reference axis and a line connecting the upper margins of both external axillary folds defines this measurement.

B. Clinical Assessment

1. Axial Cervical Rotation: Individuals were measured in a seated position using a scoliometer, specifically during neck flexion (14).

2. Range of Mandibular Movement: Participants were told to open their mouths as wide as they could without experiencing any pain, noting the distance between the central incisors of the mandibular and maxillary arches. For mandibular protrusion, participants pushed their lower jaws forward, recording the distance between the upper and lower jaws. Assessing right and left lateral movements involved participants moving their lower jaws left and right, with measurements taken from the upper incisal midline to the lower midline (15).

Photographic and clinical evaluations were performed by only one researcher.

Statistical Analysis

Data from a pilot study with 20 participants—10 with scoliosis and 10 healthy controls—were used to determine the sample size. The calculation was based on 95% power with an effect size of 1.065 to detect a difference in mean Facial asymmetry (middle face) of 3.25 (0.77) units between the scoliosis and control groups. Power analysis recommended that a total of 21 participants would be required to detect minimum differences for each group. An alpha error of 5% was considered statistically significant.

The frequency (%) for categorical data and the mean (SD) for continuous variables were used to display descriptive statistics. For comparisons between two groups, the independent samples t-test was used for variables that met the assumption of normality, while the Mann–Whitney U test was applied to data that did not meet the assumption of normality. In all tests, the significance level was determined to be $p < .05$. Analyses were performed using SPSS for Windows version 26.0 (SPSS Inc., Chicago, IL).

RESULTS

The study included 62 adolescent girls, 31 girls with scoliosis, and 31 healthy girls. The mean age was 14.5 (1.78) years for the scoliosis group and 14.09 (2.29) years for the controls. The mean Cobb's angle of the double major (primary thoracal) and main thoracal was 27.17 (7.61) ° in the scoliosis group. As an initial analysis, we assessed whether baseline demographics were different between groups, and no statistically significant differences were observed (Table 1).

Table 1. Demographic and Scoliosis-Specific Characteristics of the Participants, values are given as mean (SD), min-max.

	Scoliosis Group (n=31)	**Control Group (n=31)**	***p* value**
Age (years)	14.54 (1.78) 11-17	14.1 (2.3) 11-17	0.246
Height (cm)	163.45 (6.70) 151-181	161.87 (9.21) 142-182	0.443
Body mass (kg)	55.80 (7.44) 40-76	53.48 (8.68) 34-74	0.263
BMI (kg/m^2)	20.85 (2.16) 17.19-26.31	20.36 (2.69) 15.7-27.01	0.437
Cobb angle of the primary curve (°)	27.10 (7.61) 15-40	n/a	n/a
Curve Pattern (R) n (%)			
Single T **Double Major T**	10 (32.3%) 21 (67.7%)	n/a	n/a

SD: standard deviation, BMI: Body Mass Index, n/a: not available.

The means and standard deviations of the clinical and photographic evaluations of the assessed facial, mandibular, neck, and shoulder parameters were compared between the groups and are presented in Table 2.

According to the results of the facial asymmetry index, the mean asymmetry was highest in the mouth asymmetry (for scoliosis, 5.30 (8.82) for control, 1.55 (3.89)). The scoliosis group also had statistically higher levels of mid-face asymmetry and eye asymmetry (p<0.001). The mean right and left neck trapezium angle ratios were more asymmetric in the scoliosis group (1.14 (0.18) vs. 0.99 (0.37), p<0.001). Shoulder and axilla height differences were also lower in the control group (Table 2). Only the forward movement of the mandible showed a significant difference when comparing mandibular mobility.

Table 2. Comparison of Head, Neck and Shoulder Related Outcomes Between Scoliosis and Control Groups, mean (SD)

	Scoliosis Group (n=31)	**Control Group (n=31)**	***p* value**
Facial asymmetry index (%)			
Eye	1.62 (1.84)	1.08 (3.57)	***<0.001****
Middle face	3.46 (4.25)	0.70 (2.00)	***<0.001****
Mouth	5.30 (8.82)	1.55 (3.89)	***0.01****
Neck and Shoulder asymmetry (°)			
LRTA	1.14 (0.18)	0.99 (0.37)	***<0.001****
SHDA	2.06 (1.07)	1.09 (0.61)	***<0.001****
AHDA	2.88 (1.16)	1.80 (0.78)	***<0.001****
Mandibular mobility (cm)			
Depression	4.12 (0.79)	3.77 (0.84)	0.306
Protrusion	0.31 (0.13)	0.59 (0.79)	***0.010****
Right Deviation	0.66 (0.28)	0.68 (0.13)	0.736
Left Deviation	0.78 (0.33)	0.69 (0.14)	0.181
Axial Cervical Rotation (°)	3.17 (1.48)	0.43 (0.58)	***<0.001****

LRTA: Left/right trapezium angle, SHDA: Shoulder height difference angle, AHDA: Axilla height difference angle, SD: standard deviation. *p<0.05 statistical significance.

DISCUSSION

A three-dimensional spinal deformity called scoliosis results in body asymmetry. According to the literature, girls' scoliosis is mostly linked to the shoulders, waist, breasts, and pelvis asymmetry (16). Although the sensitivities of parents and individuals toward body asymmetry have been evaluated using questionnaires, little attention has been given to asymmetries in non-trunk areas caused by scoliosis (17). This research focused on exploring how facial, neck, and shoulder asymmetric patterns relate to idiopathic scoliosis in adolescents, and on comparing them with healthy peers to determine whether such asymmetry may serve as a clinical indicator of scoliosis. The findings revealed that participants with AIS exhibited greater facial, neck, and shoulder asymmetry, along with increased mandibular protrusion.

Robinson et al. (18) highlighted that an aesthetically balanced face depends on the symmetry of skeletal structures and soft tissues. While facial asymmetry is typically diagnosed by specialists using posteroanterior cephalograms or 3D skeletal computed tomography, these methods primarily focus on skeletal structures. However, according to Haraguchi et al. (19) pointed out, soft tissue asymmetry generally tends to be less noticeable compared to skeletal asymmetry. In this study, the present study prioritized soft tissue evaluation using 2D photographic analysis, which offers a clinically relevant and accessible means of identifying facial asymmetry.

A study involving 1029 adolescents found no association between trunk asymmetry and craniofacial asymmetry (20). Likewise, Turhan et al. (21) found no noticeable differences in particular facial landmark measurements when compared to the control group. Unlike Turhan et al.'s approach, which assessed trunk asymmetry using anterior trunk rotation (>7°), our study employed Cobb angle assessment from X-ray evaluations and found a significant difference between the control and scoliosis groups. Notably, facial asymmetry may also be an AIS finding and warrants evaluation in future studies.

In the literature, it is hypothesized that the chronic effects of head anomalies associated with various postural anomalies may be responsible for various craniofacial orthopedic and orthodontic conditions. In a study by Segatto et al., the mean midline deviation and functional asymmetry index were significantly higher in the scoliotic group (22). Consistent with the findings of other studies, individuals with scoliosis showed greater eye, midface, and mouth asymmetry according to the midline-based asymmetry index compared to the control group.

An additional study reported a connection between head posture and the vertical alignment of the mandible, which is influenced by the cervical vertebrae. Variations in the growth patterns of the muscles and fascia connected to the mandible are the cause of this relationship (23). Maintaining the head in an upright posture involves coordinated tension across the cranio-cervical skeletal system, muscle-fascia layers, and neural pathways linking oral and cervical areas. Sakaguchi et al. examined how mandibular positioning and body posture influence each other in a bidirectional manner. Their findings led to the conclusion that alterations in mandibular position have a direct effect on body posture. In contrast, adjustments in body posture were shown to alter mandibular alignment (24).

Literature suggests that the mandible functions like a stabilizing pole, influencing posture while also being influenced by it. According to the existing research, asymmetries are more frequently found in the lower face than in the upper face (25). In a cephalogram study by Lippold et al., mild maxillary protrusion, mandibular retrusion, and deviation of the facial midline were identified (26). Our study suggests a decreased protrusion due to potential mandibular retrusion; however, the differences in L-R maxillary deviations were not found to be statistically significant. We suggest that the decrease in mandibular protrusion may result from the adaptation of the muscles or fascial structures of the neck-head-trunk to postural alterations caused by the scoliosis curve.

Modifications in the muscular segment result in the lengthening and contraction of neighboring segments. Disruptions in one muscle group have a cascading impact on the surrounding muscles, fascia, and associated structures. The cervical spine acts as a link between the head and the trunk. Patients with scoliosis showed more asymmetry in the right and left trapezius angles than the control group. This asymmetry can be attributed to alterations in the cervical spine (27).

The Left/Right ratio of the Trapezium Angle was found to be directly related to both radiological parameters and clinical assessment in individuals with scoliosis. Matamalas et al. (28) found a moderate correlation ($r < 0.6$) between the SHD, AH, and LRT angle among individuals with idiopathic scoliosis. However, they emphasized that the SHD angle might serve as a standard parameter for clinical evaluation but noted a weak connection with the AHD angle. As opposed to the conclusions of Ono et al. (29), the LRT angle was considered inadequate for the clinical assessment of shoulder region balance. In our study, we observed greater asymmetry in all three parameters in the scoliosis group when compared to the control group.

Kim and Hwang (30) reported that individuals with jaw asymmetry tend to tilt their heads as a compensatory response to the imbalance. They also stated that as the severity of jawline asymmetry increases, the head-tilting behavior becomes more prominent, which may represent a compensatory mechanism aimed at maintaining postural balance. Prior studies have established a connection between head posture and mandibular deviation in scoliosis patients (31). Our results suggest that the asymmetry index of the mouth may be related to cervical flexion and left lateral flexion range of motion. Therefore, it can be inferred that the asymmetrical effects of scoliotic deformities also extend to segments closer to the trunk, such as the head, impacting cervical mobility, mandibular movements, and facial anthropometric changes.

One limitation of this study was that it would be better to add a comparison of facial anthropometric measurements with a cephalometric assessment and a self-reported questionnaire, which evaluated mandibular function, to the measurement outcomes. Thus, it will be possible to assess whether changes in mandibular-facial parameters affect quality of life. The sample of this study consisted of adolescent girls with idiopathic scoliosis with curves of a wide range of magnitude. Results may differ according to curve magnitude or patterns. However, this study presents preliminary findings regarding neck and facial asymmetry profiles, which should be considered in addition to the trunk region in AIS.

CONCLUSION

Based on our study's findings, scoliosis-related asymmetry is not limited to the trunk but also affects the neck and face. A multidisciplinary approach involving orthopedic specialists, physiotherapists, orthodontists, dentists, and plastic surgeons may benefit scoliosis patients.

Most studies on the appearance of scoliosis in adolescents focus primarily on the trunk and pelvis asymmetry. However, our findings highlight the need to consider asymmetry in the neck and face as well. This perspective aims to emphasize the importance of a comprehensive approach to understanding the impact of scoliosis-related deformities in various anatomical regions. To further enhance our understanding of this matter, additional research is needed.

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