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Evaluation of ophthalmologic abnormalities in pediatric patients with idiopathic scoliosis: A prospective, cross-sectional, case-control study

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Idiopathic scoliosis (IS) is the most common pediatric spinal deformity, characterized by asymmetric deformity of the spine in three planes (coronal, sagittal, and axial) which appears in childhood or adolescence and has no underlying structural, neuromuscular, or congenital cause that can be identified.[1] Although it is most commonly diagnosed during adolescence, asymptomatic cases may also be encountered in early childhood. Scoliosis not only affects spinal morphology; it also disrupts balance, postural control, and overall musculoskeletal biomechanics, potentially negatively impacting children's quality of life, physical activity levels, and psychosocial status.[2] Epidemiological studies conducted across different geographical regions have reported varying prevalence rates of IS, ranging from 0.93 to 3.1%, depending on the characteristics of the studied population and the screening methods used.[3-5]

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ABSTRACT

Objectives: The aim of this study was to determine the prevalence and distribution of ophthalmologic abnormalities, particularly binocular vision disorders and refractive errors, in children diagnosed with idiopathic scoliosis (IS).

Patients and methods: Between September 2025 and December 2025, a total of 48 pediatric patients diagnosed with IS (scoliosis group) and 41 age- and sex-matched healthy children (control group) were included in this prospective, cross-sectional, case-control study. The Cobb angle (≥ 10°) was considered in the scoliosis assessment. Based on Cobb angle measurements, scoliosis patients were classified into two subgroups: mild scoliosis (10°-20°, n = 26) and moderate scoliosis (21°-40°, n = 22). All participants underwent a comprehensive ophthalmologic examination, including cycloplegic refraction, visual acuity levels, and near stereoscopic vision measurement.

Results: Of a total of 48 patients with IS included in the study, 14 were male and 34 were female with a median age of 14 (range, 6 to 18) years. The control group consisted of 41 participants. Of them, 16 were male and 25 were female with a median age of 11 (range, 5 to 16) years. Cervicothoracic scoliosis was identified in 30 patients (62.5%) in the scoliosis group. The number of patients with refractive error requiring glasses was significantly higher in the scoliosis group ($p = 0.030$). Stereoacuity levels were significantly lower in the scoliosis group ($p < 0.001$), and this difference was observed in both mild and moderate scoliosis subgroups. However, multivariable logistic regression analysis adjusting for age and sex revealed no independent association between scoliosis and decreased stereopsis or refractive error.

Conclusion: Children with idiopathic scoliosis exhibit reduced stereopsis and a higher frequency of refractive errors requiring spectacles. These findings suggest a potential association between scoliosis and visual function. Therefore, ophthalmologic evaluation may be considered as part of the clinical assessment of children with scoliosis.

Keywords: Idiopathic scoliosis, refractive errors, stereopsis, visual impairment.

Since the etiology cannot be fully determined, current treatment approaches are determined based on the patient's clinical presentation.

Multiple factors have been implicated in the pathogenesis of IS.[2] Therefore, identifying etiopathogenetic factors specific to IS, particularly those detectable at an early stage, may help prevent the development of spinal deformity. Previous studies investigating the etiopathogenesis of IS have reported that sensorimotor dysfunctions play a significant role in the disease process.[6,7] In particular, cases with progressive curvature have been shown to exhibit pronounced impairments in postural control.[8] Maintaining appropriate postural alignment requires effective integration of neurosensory inputs from visual, vestibular, and somatosensory receptors by the central nervous system. This integrative process is critical for generating appropriate motor responses, including compensatory eye movements and postural adjustments, to maintain balance.[9]

The visual system is a critical component that works in concert with the central nervous system to maintain postural balance, perceive head and body orientation, and generate motor responses coordinated with proprioceptive feedback.[9,10] Ophthalmologic disorders such as binocular vision abnormalities, refractive errors, convergence insufficiency, and oculomotor dysfunctions may disrupt the integration of vestibular and somatosensory inputs during childhood, thereby indirectly and adversely affecting normal spinal development.[11] Refractive errors, including myopia, hyperopia, and astigmatism, impair the clarity and accuracy of visual information reaching the central nervous system, potentially compromising the quality of visual feedback available for postural regulation.[9] Binocular vision disorders, such as stereopsis deficits, may further disrupt the integration of visual signals required for accurate spatial orientation and depth perception.[12] Given the close interaction between the visual system and postural control, ophthalmologic abnormalities, particularly refractive errors and stereopsis deficits, may play a role in the development of IS in the pediatric population.

Despite growing evidence that sensorimotor integration plays a role in IS, the contribution of visual system abnormalities remains poorly understood. Most previous studies have focused on postural control and neuromuscular factors, while ophthalmologic parameters such as refractive errors and binocular vision disorders have been investigated less frequently. Therefore, there is still limited evidence on whether visual dysfunction is associated with IS in children. In the present study, we hypothesized that children with IS had a significantly higher prevalence of ophthalmologic abnormalities compared to their healthy peers. We, therefore, aimed to determine the prevalence and distribution of ophthalmologic abnormalities, particularly binocular vision disorders and refractive errors, in children diagnosed with IS.

PATIENTS AND METHODS

This single-center, prospective, cross-sectional, case-control study was conducted at Ordu University Training and Research Hospital, Department of Orthopedics and Traumatology between September 2025 and December 2025. Children aged between 6 and 18 years having complaints or a preliminary diagnosis of scoliosis were included in the study. All patients underwent comprehensive orthopedic evaluations. Patients with a clinical suspicion of IS whose diagnosis was confirmed by spinal radiographs constituted the scoliosis group, whereas patients in whom scoliosis was ruled out were included as the control group. The age range of 6 to 18 years was chosen to reflect the full clinical spectrum of IS encountered in routine orthopedic practice, encompassing both juvenile and adolescent presentations. A total of 63 patients with suspected scoliosis were initially assessed for eligibility. Children with mental disabilities, chronic conditions that could predispose them to spinal deformities (such as osteogenesis imperfecta or endocrine disorders), neurodegenerative diseases, psychiatric disorders, developmental disorders, or poor compliance with clinical examination were excluded from the study. In addition, patients with compensatory scoliosis, a history of trauma or fracture, or those who had previously undergone bracing or surgical treatment were not included in the study. Patients with severe scoliosis (Cobb angle > 40°) were excluded, as these patients are typically candidates for surgical treatment, and advanced deformity-related compensatory mechanisms may influence postural and visual parameters. After applying the exclusion criteria, 48 patients with IS were included in the study. In addition, 41 age- and sex-matched children without scoliosis were included as the control group. The study flow chart is shown in Figure 1. A written informed consent was obtained from the parents and/or legal guardians of the patients. The study protocol was approved by the Ordu University Non-Interventional Scientific Research Ethics Committee (Date: 12.09.2025, No. 2025/279). The study was conducted in accordance with the principles of the Declaration of Helsinki.

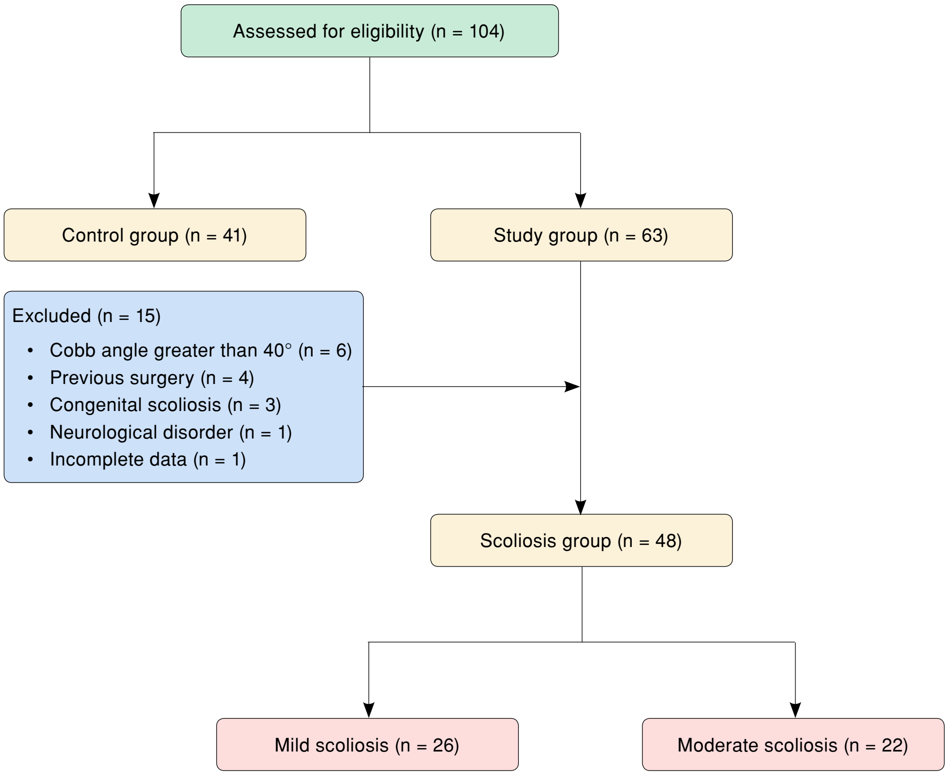

FIGURE 1. Study flowchart.

Although juvenile and adolescent IS are regarded as distinct clinical entities, the primary aim of this study was to characterize ophthalmologic findings across the IS population as a whole; age was, therefore, included as a covariate in all multivariable analyses to account for potential age-related confounding. Scoliosis was defined as a Cobb angle ≥ 10°. Based on Cobb angle measurements, scoliosis severity was classified as mild (10°-20°) or moderate (21°-40°).[13] In addition, the localization and magnitude of the scoliotic curve were recorded. Patients with findings consistent with congenital scoliosis were excluded from the study. Cobb angle measurements were performed by a single experienced orthopedic surgeon at three different time points, and the mean of the three measurements was used for analysis. Intraobserver reliability of Cobb angle measurements was assessed using the intraclass correlation coefficient (ICC), which demonstrated excellent reliability (ICC = 0.979).

The ophthalmologic examinations were performed by a single experienced ophthalmologist who was blinded to the participants' group allocation. All patients were referred from the Orthopedics and Traumatology outpatient clinic, and the ophthalmologist was not informed whether the participants belonged to the scoliosis or control group. A history of ocular disease and regular spectacle use was recorded for all participants. Visual acuity levels were assessed using a Snellen chart while participants wore their corrective spectacles, if applicable. Visual acuity values were converted to logarithm of the minimum angle of resolution (logMAR) notation for statistical analysis. A comprehensive ophthalmologic examination was performed, including cycloplegic refraction (1% cyclopentolate instilled three times at 5-min intervals, with refraction measured 30 min after the final drop), intraocular pressure measurement using non-contact tonometry (Tonoref III, Nidek Co., Ltd., Tokyo, Japan), slit-lamp biomicroscope, and dilated fundus examination. Cycloplegic refraction is considered the gold standard for objective refractive error assessment, as it eliminates the effect of accommodation, thereby providing more accurate measurements, particularly in pediatric populations, in whom accommodative tone is highest.[14] In addition, color vision was assessed, and the presence of ocular pathologies such as strabismus, amblyopia, or nystagmus was evaluated and recorded. Following completion of the ophthalmologic examinations and appropriate correction of refractive errors, stereopsis was assessed using the Titmus Stereo Test (TST) at a distance of 40 cm under normal room illumination while wearing polarized glasses. TST results were expressed in seconds of arc. Stereopsis was evaluated using the circle test component of the TST, with values ranging from 800 to 40 sec of arc. Stereoacuity deficits were associated with reduced fine motor task performance and reduced balance. Based on the final stereopsis scores, participants were classified as having good stereopsis (40-100 sec of arc) or poor stereopsis (> 100 sec of arc) to establish a threshold distinguishing good from poor stereopsis.[15,16] All ophthalmologic examinations were conducted in the morning hours (between 09:00 and 12:00) to minimize potential variability attributable to diurnal fluctuations in visual performance, thereby enhancing the standardization of data collection across participants. Measurements were based on the better-seeing eye of each participant. All examinations and measurements were performed by the same experienced ophthalmologist, and any ocular pathologies identified during the examination were recorded.

Statistical analysis

The sample size calculation was based on previously published data evaluating the relationship between refractive errors and scoliosis, with an assumed statistical power of 80% and a 95% confidence interval (CI).[17]

Statistical analysis was performed using the IBM SPSS version 25.0 software (IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test was used to check the normality of the data distribution. Continuous variables were presented in median (min-max), while categorical variables were presented in number and frequency. Categorical variables were compared using the chi-square test. The Mann-Whitney U test was used to evaluate non-parametric variables that did not show normal distribution between the two groups, and the Kruskal-Wallis test was used in cases of more than two groups. Stereopsis values were compared to the scoliosis angle values using the Spearman correlation coefficient. To evaluate the independent association between scoliosis and ophthalmologic outcomes after controlling for potential confounders, binary logistic regression analyses were performed. Poor stereopsis (> 100 sec of arc) and refractive error requiring spectacles were entered as dependent variables in separate models. Scoliosis status was included as the primary independent variable, while age and sex were included as covariates. Results were expressed as odds ratios (ORs) with 95% CIs. Model performance was evaluated using the Nagelkerke R^2 statistic. A p value of < 0.05 was considered statistically significant.

RESULTS

Of a total of 48 patients with IS included in the study, 14 were male and 34 were female with a median age of 14 (range, 6 to 18) years. The control group consisted of 41 participants. Of them, 16 were male and 25 were female with a median age of 11 (range, 5 to 16) years. There were no significant differences between the groups in terms of age or sex distribution (Table I). Twenty-six (54.17%)

TABLE I
Demographic and clinical characteristics of the participants

	Scoliosis group (n = 48)				Control group (n = 41)				
Parameter	n	%	Median	Min-Max	n	%	Median	Min-Max	*p*
Age (year)			14	6 to 18			11	5 to 16	0.169*
Sex									0.330†
Male	14				16				
Female	34				25				
Visual acuity (logMAR)			0.0	0.0 to 0.4			0.0	0.0 to 0.4	0.116*
Stereopsis (seconds of arc)			50	40 to 200			40	40 to 200	**<0.001***
Stereopsis, > 100	9	18.75			2	4.88			**0.045†**
Spherical equivalent (D)			–0.44	–5 to 1.25			–0.25	–1.62 to 0.75	0.134*
Refractive error	26	54.17			13	31.71			**0.030†**
With spectacles	11	22.92			6	14.63			0.320†

D, diopter; *, Mann-Whitney U test; † chi-square test.

of the scoliosis patients had mild scoliosis, while 22 (45.83%) had moderate scoliosis. Thirty (62.5%) patients had cervicothoracic scoliosis. None of the participants had color vision deficiency. No anterior or posterior segment pathology that could affect visual function was detected in any participant. Strabismus was observed in three patients with moderate scoliosis, and one of these patients had an abnormal head posture associated with strabismus. Corrected visual acuity was similar between the groups. However, the number of patients with refractive errors requiring glasses was significantly higher in the scoliosis group (p = 0.030). Among the 11 (22.92%) patients in the scoliosis group who regularly used glasses, 4 (8.33%) had inadequate glasses.

The mean stereoacuity was also significantly lower in the scoliosis group compared to the control group (p < 0.001) (Table I). In addition, the participants were evaluated for the presence of poor stereopsis (stereopsis > 100 sec of arc), and the number of patients with poor stereopsis was found to be significantly higher in the scoliosis group (p = 0.045).

According to the severity of scoliosis, the mean stereoacuity was also significantly lower in the mild and moderate scoliosis groups compared to the control group (p < 0.001) (Table II). However, no significant difference in stereoacuity was observed between the mild and moderate scoliosis groups. The visual acuity of the better eye was similar between the groups (p = 0.286). Patients with the myopic refractive error were higher in the all groups (p = 0.317).

The mean Cobb angles in the mild and moderate scoliosis groups were 14.35±2.78 and 28.41±11.32, respectively (p = 0.001) (Table II). A correlation analysis was performed between Cobb angle values and stereopsis. No significant correlation was found between stereopsis values and Cobb angle degrees (r = −0.153, p = 0.301). Intraobserver reliability analysis demonstrated excellent agreement for Cobb angle measurements (ICC = 0.979).

Binary logistic regression analyses were conducted to assess the independent associations between scoliosis group membership and the two primary ophthalmologic outcomes after adjusting for age and sex. In the model predicting poor stereopsis, scoliosis group membership was not independently associated with poor stereopsis (OR = 1.975, 95% CI: 0.344-11.345, p = 0.445). Similarly, in the model predicting refractive error

TABLE II

Visual outcomes during examination in scoliosis cases and control group

Characteristic	Mild scoliosis (n = 26)				Moderate scoliosis (n = 22)				Control group (n = 41)				*p*
	n	%	Median	Min-Max	n	%	Median	Min-Max	n	%	Median	Min-Max	
Stereopsis (seconds of arc)			60	40 to 200[a]			50	40 to 200[a]			40	40 to 200[b]	**< 0.001***
Stereopsis, > 100	6	23.08			3	13.64			2	4.88			0.083†
Spherical equivalent (D)			−0.31	−5 to 1.25			−0.5	−4.5 to 0.75			−0.25	−1.62 to 0.75	0.317*
Visual acuity (Snellen chart)			0.0	0.0 to 0.4			0.0	0.0 to 0.2			0.0	0.0 to 0.4	0.286*
Refractive error	14	53.84			11	50.0			13	31.70			0.145†
Cobb angle (degree)			14	11 to 20			25.5	21 to 39			-	-	**< 0.001‡**

D, diopter; Same letters denote the lack of statistically significant differences between groups (for stereopsis analysis). *, Kruskal-Wallis tesü; †, Chi-Square test; ‡, Mann-Whitney U test. Same letters denote the lack of statistically significant differences between groups (for stereopsis analysis).

TABLE III
Binary logistic regression analyses for ophthalmological outcomes in pediatric patients with idiopathic scoliosis

Variables	OR	95% CI	*p*
Model 1: Dependent variable-Poor stereopsis (> 100 seconds of arc)			
Scoliosis group (ref: Control)	1.975	0.344-11.345	0.445
Sex, Female (ref: Male)	2.641	0.495-14.107	0.256
Age (year)	1.274	0.949-1.709	0.107
Nagelkerke R^2 = 0.186 | n = 89			
Model 2: Dependent variable-Refractive error requiring spectacles			
Scoliosis group (ref: Control)	1.440	0.526-3.946	0.478
Sex, Female (ref: Male)	2.412	0.942-6.179	0.066
Age (year)	1.090	0.932-1.274	0.280
Nagelkerke R^2 = 0.127 | n = 89			

OR, odds ratio; CI, confidence interval. Covariates included in both models: age and sex. Reference categories: Control group, Male sex.

requiring spectacles, scoliosis group membership was not independently associated with refractive error after adjustment (OR = 1.440, 95% CI: 0.526-3.946, p = 0.478) (Table III).

DISCUSSION

In the present study, we investigated the prevalence and distribution of ophthalmologic abnormalities, particularly binocular vision disorders and refractive errors, in children diagnosed with IS. Our study results demonstrated that refractive errors requiring spectacle correction were significantly more frequent in the scoliosis group, and that stereopsis levels were markedly reduced. In particular, stereopsis values were significantly lower in both the mild and moderate scoliosis groups compared to the control group. These findings suggest that visual system pathologies in children with IS may be an important factor that should not be neglected.

The visual system plays a significant role in maintaining postural control, perceiving head-body orientation, and directing movement in a manner consistent with proprioceptive feedback. Several studies have identified the anatomical interaction between scoliosis and the visual system. Batın et al.[18] evaluated the medial/lateral eye muscles in scoliotic and healthy individuals using magnetic resonance imaging and reported that the volume of the medial rectus muscle was significantly reduced and showed significant asymmetry in adolescent IS patients compared to asymptomatic individuals. Furthermore, the authors emphasized that changes in the biomechanics of the spine might parallel the structure of the eye muscle, but the causal level of this relationship has not yet been clearly elucidated. In our study, we evaluated the clinical manifestations of scoliosis, not its effect on structural changes in the eye, and determined that children with IS had significant impairments in visual functions such as refractive error and stereopsis. Our findings support the changes identified anatomically by Batın et al.[18] in clinical terms. Therefore, our study demonstrates that ophthalmologic evaluation should be part of a comprehensive approach in individuals with scoliosis.

Many studies in the literature have investigated the effects of visual impairments on posture alignment. De Pádua et al.[19] investigated postural abnormalities in pediatric patients aged between 5 and 12 years with and without congenital visual impairment. They found that postural abnormalities such as head tilt, shoulder asymmetry, spinal lateral deviation, increased thoracic kyphosis, and decreased lumbar lordosis significantly increased in children with congenital visual impairment. In contrast, our study compared visual functions between children with and without a diagnosis of scoliosis. Although visual acuity levels were similar between the groups, a significant weakness in stereopsis levels was identified in patients with scoliosis. In our study, myopia was found to be the most common refractive error among children with scoliosis, and the number of patients with refractive errors requiring spectacles was significantly higher compared to the control group. Although both studies evaluated different patient groups, these findings are broadly consistent and suggest a possible association between visual function and postural control in children with IS. However, given the cross-sectional design of both studies and the heterogeneity of the patient populations, causal inferences cannot be drawn. Further prospective studies are needed to clarify the relationship between these factors.

Previous studies have also suggested an association between visual impairment and spinal axial deviations in children. A recent systematic review and meta-analysis reported that eye diseases were associated with approximately three times greater odds of developing scoliosis, and proposed that disruption of visual verticality perception may lead to coronal head tilt, which in turn could contribute to spinal curvature through altered postural regulation during growth.[11,20] In a study conducted by Catanzariti et al.,[11] children with congenital or severe visual impairment had a higher incidence of body asymmetries and scoliosis. In the aforementioned study, spontaneous nystagmus and strabismus were the most common ophthalmoplegic pathologies detected. In our study, no spontaneous nystagmus was detected in any of the patients; however, strabismus was present in three patients with moderate scoliosis and one of these patients had an abnormal head position due to strabismus. In contrast, the significantly higher rate of refractive errors requiring spectacles in the scoliosis group suggests that visual impairments reach an earlier or more pronounced clinical level in this patient group.

Myopia is one of the most common refractive errors in childhood and has been associated with various musculoskeletal disorders in the pediatric population due to reduced visual input. In a study conducted by Cai et al.[21] among school-aged children, female sex and myopia were significantly associated with scoliosis. Egorova et al.[22] on school-aged children, individuals with high myopia had a significantly higher incidence of many postural disorders, including scoliosis, kyphosis, hyperlordosis, and chest and lower extremity deformities, compared to healthy individuals. Similarly, in our study, myopia rates were higher in children with scoliosis, consistent with other studies in the literature. Additionally, 54.17% of scoliosis patients had refractive errors requiring spectacles, a significantly higher rate compared to the control group. The high female sex ratio in the scoliosis patient group in our study supports the epidemiological distribution mentioned in the study of Cai et al.[21]

On the other hand, stereopsis is a parameter which was evaluated differently in our study compared to other studies. This assessment revealed that depth perception, a clinical indicator of binocular vision, significantly reduced in patients with scoliosis. Although strabismus is a known cause of decreased stereopsis, only a small proportion of participants in our cohort had strabismus, suggesting that other mechanisms may also contribute. In particular, 54% of patients with scoliosis had refractive errors requiring spectacle correction; this may further compromise stereoacuity in this population. These findings suggest that comprehensive ophthalmologic evaluation, including stereopsis assessment, may be beneficial in children with IS, particularly during periods of active growth. Early identification of the underlying cause may enable timely intervention during critical periods of visual development in childhood, potentially improving stereoacuity and supporting the development of binocular vision.[16,23] When patients in the scoliosis group were divided into subgroups based on Cobb angle as mild and moderate; although the stereopsis level was lower in the mild and moderate scoliosis group compared to the control group, no significant correlation was found between stereopsis level and scoliosis severity. We can speculate that this lack of correlation may be attributable to the relatively small sample sizes within the subgroups. Nevertheless, our study suggests the relationship between stereopsis, myopia and scoliosis and demonstrates that functional visual impairments in children with scoliosis require a more comprehensive evaluation.

A previous study reported that the predominant curvature pattern observed in adult women with visual impairment was thoracolumbar scoliosis.[24] In the study by Catanzariti et al.[11] on pediatric patients, cervicothoracic curvature had a high incidence. In our study, cervicothoracic curvature was detected in 62.5% of scoliosis patients. Since our study evaluated pediatric patients with IS, it can be considered an expected finding that visual compensation is more pronounced in the head-neck related cervicothoracic region.

Despite providing valuable contribution to the evaluation of visual functions in children with scoliosis, this study has certain limitations. First, the cross-sectional design limits the ability to establish causal relationships between scoliosis and ophthalmologic findings; however, this design remains appropriate for describing the observed associations. Second, the inclusion of both juvenile and adolescent IS patients may introduce a degree of clinical heterogeneity; although age was included as a covariate in the multivariable analyses to partially account for this variability, future studies focusing on homogeneous age subgroups would provide more accurate estimates. Third, the moderate sample size precluded subgroup analyses according to scoliosis type and severity, and data from larger, multi-center cohort studies would further strengthen the generalizability of the findings. Additionally, although binary logistic regression analyses were performed to adjust for potential confounders, scoliosis group membership was not independently associated with poor stereopsis or refractive error after adjustment for age and sex, likely reflecting the limited statistical power attributable to the small number of poor stereopsis events (n = 11); larger prospective studies are therefore needed to clarify these associations. Despite these limitations, the use of a matched control group and the objective assessment of stereopsis and refractive errors using standardized methods constitute the principal methodological strengths of this study, supporting the internal validity of the reported findings.

In conclusion, our study demonstrates that children with IS exhibit significantly reduced stereopsis and a higher prevalence of refractive errors, particularly myopia requiring spectacle correction. Comparisons with the control group suggest that scoliosis may be associated not only with spinal deformity but also with alterations in visual function. Although a causal relationship cannot be established due to the cross-sectional design of the study, the observed visual impairments indicate that ophthalmologic evaluation should be an integral component of the clinical follow-up in children with scoliosis. These findings highlight the importance of early diagnosis and a multidisciplinary approach, while further large-scale studies are needed to more fully clarify the relationship between scoliosis and the visual system.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: A.A.S: Conception and design, collection and assembly of data, literatüre review and writing of the original draft; A.K.S: Conception and design, collection and assembly of data, analysis and interpretation of the data, critical review and editing. All authors read and approved the final manuscript.

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