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ORIGINAL ARTICLE

The burden of scoliosis: a nationwide database study on demographics, incidence, and surgical rates

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Abstract

Introduction Scoliosis is characterized as a three-dimensional deformity of the spine, affected by variety of factors, including biological, mechanical, hormonal, and genetics.

Methods Our study's primary objective was to delineate the demographics, incidence, and prevalence of scoliosis from a nationwide perspective, analyze the surgical intervention rates, with the aim of offering more insightful guidance to orthopedic physicians. This nationwide cohort study was conducted from digital database for healthcare information management. Relevant population data, for children under 18 years old, was extracted from the official government census within the period of January 2015 to December 2022. Utilizing diagnostic code of M41 [Scoliosis] was used to define the patient pool from ICD-10. Demographic variables, type of operations (posterior only, anterior only, or combined), and complications were documented. Incidence and prevalence values were calculated using population figures and case numbers.

Result There were 276,521 patients with an average incidence of 129 per 100,000. Frequency of females was 1.45 times greater than that of males ($p < 0.001$). A total of 10,417 surgeries were performed in 10,311 patients during the inspection period (3.8% of all cases). Posterior fusion was by far the most common surgical approach ($n = 10.111$; 97%) followed by anterior fusion ($n = 200$; 1,9%).

Conclusions Our findings reveal a significant increase in the average incidence of scoliosis diagnosis, rising from 107 per 100,000 individuals in 2015 to 161 per 100,000 in 2022. Scoliosis now impacts an estimated 1.2% of children and adolescents in Turkey. The risk is 1.45 times higher in females than in males.

Keywords Nationwide · Scoliosis · Incidence · Posterior fusion

Introduction

Scoliosis is characterized as a three-dimensional deformity of the spine, with adolescent idiopathic scoliosis (AIS) being the most prevalent cause [1, 2]. Although the etiology of scoliosis remains unclear, particularly in idiopathic cases, it is thought that a variety of factors, including biological, mechanical, hormonal, and genetic factors, contribute to its onset and progression [1–3].

Early identification and effective intervention could stop or slow the curve progression of mild scoliosis before skeletal maturity [4]. It is typically more prevalent in the female population, with females exhibiting a greater degree of progression than males [1, 5]. The prevalence of infantile idiopathic scoliosis (IIS) and juvenile idiopathic scoliosis (JIS) is known to be much lower than that of AIS, and the distribution of these conditions among males and females differs significantly from that of AIS [6, 7].

Previous investigations on the subject have predominantly comprised cross-sectional studies utilizing a school-based screening program as a means of approximating the prevalence in the wider population [8–11]. The prevalence of scoliosis with a Cobb angle above 10° has been reported to vary from 1 to 12% on a global scale [1, 9, 11–14]. According to the results of the studies conducted in Turkiye before 2020, scoliosis prevalence varies between 15 and 640 patients per 100,000 individuals [15–17]. A recent study by Yilmaz et al. conducted a school-based screening 16,045 students and reported the overall prevalence of AIS as 2.3% (3.1% in

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females and 1.5% in males) in Turkiye. Additionally, 98.8% of cases were confirmed radiologically [9].

Understanding demographics is a fundamental aspect in guiding clinical practice, steering research, and enhancing awareness among orthopedic surgeons. Consequently, our study's primary objective was to delineate the demographics, incidence, and prevalence of scoliosis from a nationwide perspective, encompassing all population categories. Moreover, we sought to conduct a comprehensive analysis of surgical intervention rates in scoliosis patients across the country, with the aim of offering more insightful guidance to orthopedic physicians.

Materials and methods

This nationwide retrospective cohort study (level of evidence 4) was conducted adhered to the principles outlined in the Declaration of Helsinki. Approval was obtained from the Turkish Ministry of Health, and informed consent for retrospective data analysis was waived (95741342-020/27112019). The citizens of Turkiye are each assigned a unique civil registration number, which is utilized in healthcare engagements to ensure comprehensive interconnectivity between healthcare registries. All patient records are stored on a digital database known as E-Nabız, serving as a centralized platform for healthcare information management [18]. This database collects and includes extensive information, including not only performed procedures and prescribed medications, but also diagnoses, comorbidities, and demographic data of the insured patients.

Relevant population data, for children under 18 years old, was extracted from the official government census within the period of January 2015 to December 2022. By utilizing the E-Nabız database system, the 10th revision of the international classification of diseases (ICD) diagnostic codes were employed to recognize patients with newly diagnosed scoliosis (M41). All diagnostic codes were registered by licensed doctors in medical institutions and the threshold for cure is > 10° at the initial visit. This code is further subdivided into 8 distinct categories, which are itemized below:

I. M41.0 Infantile idiopathic scoliosis.
II. M41.1 Juvenile and adolescent idiopathic scoliosis.
III. M41.2 Other idiopathic scoliosis.
IV. M41.3 Thoracic scoliosis.
V. M41.4 Neuromuscular scoliosis.
VI. M41.5 Other secondary scoliosis.
VII. M41.8 Other forms of scoliosis.
VIII. M41.9 Scoliosis, unspecified.

The next step involved dividing our patient pool into 2 age groups, namely 0–10 years of age, 10–18 years of age. All outcome variables were extracted and collected from the medical records of patients stored in the E-Nabız database. During the data extraction process, it was observed that there was a minimal (< 0.1%) amount of non-extractable data pertaining to geographic distribution, which were excluded from the study.

Outcome variables

Patient-related variables included age, gender, geographic distribution, and ethnic background. The institution types comprised public hospitals, private hospitals, and public and private university hospitals.

The imaging variables included the need and number of long-standing posterior-anterior X-ray scans of the whole spine.

The treatment-related variables, including physical therapy sessions applied, the type of treatment (non-surgical or surgical), type of operations (posterior only, anterior only, or combined) were documented. Further analysis was based on the surgical approach and specific operation procedure codes that can be found on the Turkish Ministry of Health's official website (https://skrs.saglik.gov.tr/). All operations were confirmed by registering the procedural codes;

I. Posterior fusion (613.630, 613.640, 614.020, 614.030, 614.040, 614.050, 614.060, 613.650, 613.660, 613.910, 613.990, 614.000).
II. Anterior fusion (613.830, 613.840, 613.870, 613.880, 613.890, 613.900, 613.920, 613.930).

The *primary outcome measures* were to analyze the frequency parameters such as, incidence, age at initial diagnose, gender differences, treatment modalities, and complication including surgical site infection (SSI), mechanical failure, neurologic deficit, or pseudarthrosis.

Incidence of scoliosis

Incidence and prevalence values were calculated using population figures and case numbers. An analysis was conducted to compare the incidence of scoliosis with age-matched normal populations, utilizing data obtained from the government statistics office. The incidence rates were further assessed based on two age categories: 0–10 years and 10–18 years. Differences in incidences were further analyzed using 7 regions of Turkiye (Marmara, Mediterranean, Central Anatolia, Aegean, Southeastern Anatolia, Black Sea, Eastern Anatolia).

Secondary outcome measures were to evaluate gender-related differences in the management of scoliosis and regional preferences of physicians among Turkiye.

Statistical analysis

Descriptive statistics were presented as mean ± standard deviation or median (minimum–maximum) depending on the assumption of normal distribution for quantitative variables, and frequency (percent) for qualitative variables. The assumption of normal distribution of quantitative data was analyzed with the Shapiro–Wilk Test. The patients' quantitative data were evaluated with the Mann–Whitney *U* Test and Kruskal–Wallis Test. The statistical significance level was accepted as 0.05, and the Statistical Package for Social Sciences (SPSS, Version 25.0, Chicago, IL) was used for the analysis.

Results

After excluding patients with insufficient medical data, the number of patients diagnosed with scoliosis between January 2015 and December 2022 was 276,521. The overall prevalence throughout the inspected duration was 1160 per 100,000 population (1870 per 100,000 population in females vs. 314 per 100,000 population in males; $p < 0.001$), and the average incidence was 129 per 100,000 population.

The cohort consisted of 163,497 (59.1%) females and 113,024 (40.9%) males. The distribution was greater in females by 1.45 times that of males. ($p < 0.001$). In other words, female-to-male ratio is approximately 145:100.

There were 274,678 (99.3%) Turkish and 1,832 (0.7%) non-Turkish children. At the time of initial diagnosis, the mean age for girls was statistically older than boys (12.8 ± 3.6 years old vs. 12.6 ± 4 years old, $p < 0.001$) however, had no clinical significance (Fig. 1). The highest reported case was among males and females between ages [13–16].

According to the analysis of regional incidence, western provinces showed higher incidences than eastern provinces in all age groups. The first 20 provinces with the highest diagnose and incidence of scoliosis are shown on the Fig. 2. The distribution of age at diagnose was similar across the country (Fig. 3).

We also identified the types of medical institutions where scoliosis patients were diagnosed, underwent operations, and had follow-up visits. The diagnosis of idiopathic scoliosis occurred mostly in public tertiary hospitals and universities (73.9%), followed by private hospitals and clinics (20.3%), general hospitals (4.8%), primary care centers (0.8%), and other institutions (0.2%).

Imaging

Of the 276,521 scoliosis patients conducted from the database, 92.5% had long-standing posterior-anterior spine X-ray was taken to confirm the diagnosis in addition to a physical exam. As some patients received multiple X-rays, the average number of X-ray taken was 2.9 ± 2.7 (median: 2 (1–55)) among those who were screened.

Surgical treatment

A total of 10,417 surgeries were performed in 10,311 patients during the inspection period (3.8% of all diagnosed cases), of which 6,780 cases (65.7%) were performed in females, while 3425 cases (34.3%) were performed in males.

According to the age preference, 81.6% of patients (8,415 patients) underwent surgery between the ages of 10 and 18 years old. Surgical treatment was most frequently performed in public tertiary hospitals and universities (87.4%), followed by private hospitals (11.2%), and other institutions (1.4%).

Posterior fusion was the most common surgical approach ($n = 10{,}111$; 97%) followed by anterior fusion ($n = 200$; 1,9%) and anteroposterior fusion ($n = 106$; 1,1%). There was a statistically significant shift toward the proportion of posterior fusion ($p < 0.001$) with a resultant decrease in anterior and anteroposterior fusion over the inspection period.

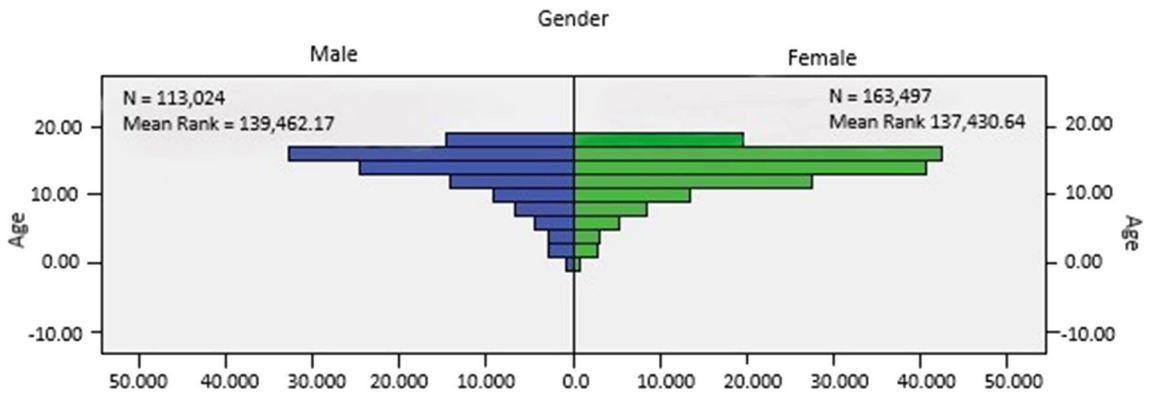

Fig. 1 Age distribution among genders

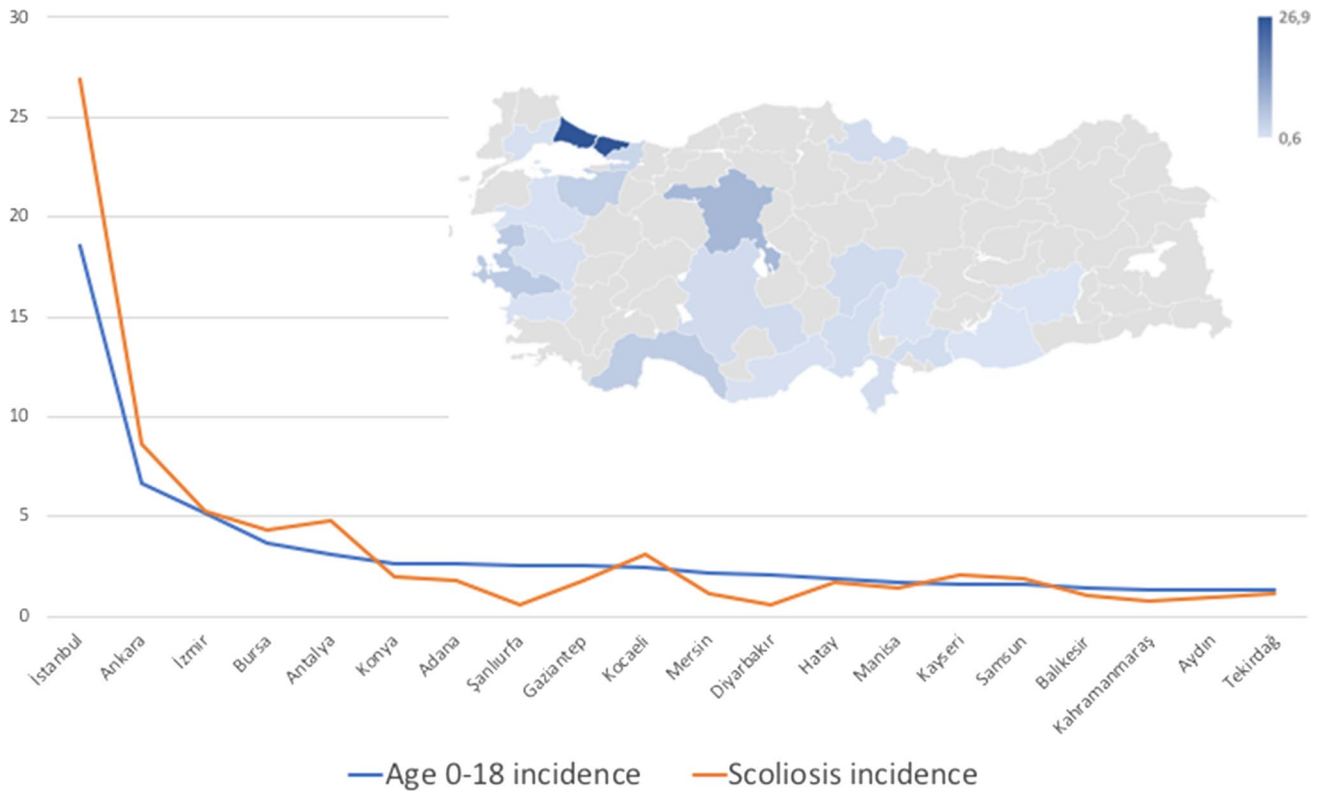

Fig. 2 Provinces which had higher incidence of scoliosis across Turkiye

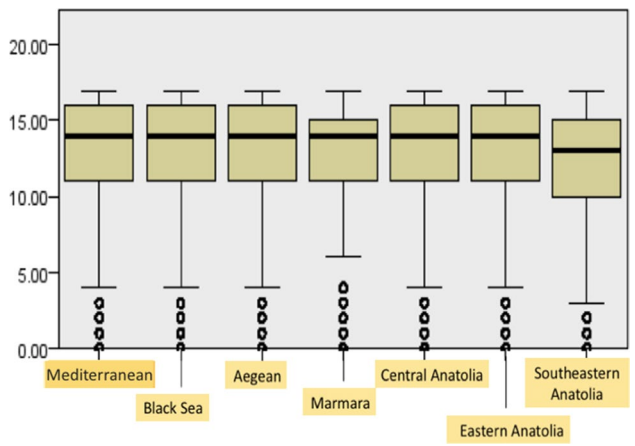

Fig. 3 The distribution of age at diagnose across regions of Turkiye

Complications

There were 1423 (13,6%) secondary procedures in 1382 patients (13,4 of all cases) through the inspection period, which are listed as a complication, mostly due to surgical site infection (SSI), new neurologic deficit, implant-related mechanical failure. The number of complications showed an increasing trend until 2019, however, remained steady in the following years (Fig. 4).

Unfortunately, 311 (%0.11) individuals died within the inspected duration, which most of them was not related to the spinal deformity.

Discussion

Turkiye transitioned from a paper version to digital personal health records in 2015. A personal health record (PHR) is the last link in the chain of health data digitalization. PHR's are generated by physicians and hospitals through diagnoses, pharmacies, treatments, and electronic infrastructure. In 2022, the number active PHR users was 68 million, that is, 80.0% of the population. In addition, e-Nabız has an adoption rate of 94% among users aged 0–18 years [18, 19].

In the screening studies, there are always some differences from the study population and the general population, including variation of ethnic diversity and levels of education. However, nationwide database studies produce a powerful insight to the nation's health politics. These databases have been used to produce estimates for incidence of a variety of medical conditions, such as breast cancer, prostate

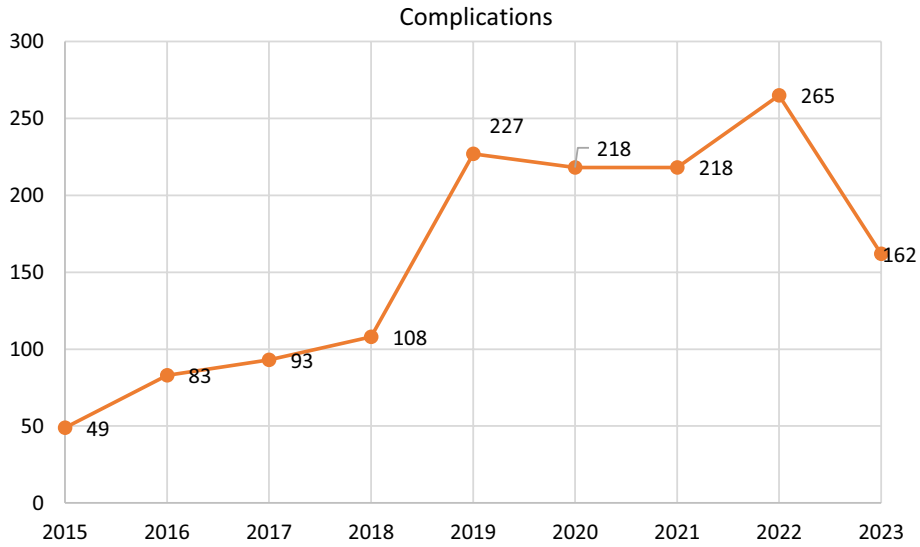

Fig. 4 The number of secondary procedures through the inspection period mostly due to infection, mechanical failure or pseudarthrosis

cancer, hip fractures, osteoporosis, and cardiovascular disease with similar results internationally [20].

Modern data gathered from nationwide databases on the incidence of commonly seen disease, such as scoliosis, may provide further insight regarding the role for screening programs, which is currently debated all over the world [21]. While, many countries adopted a school-based universal scoliosis screening, budgetary pressures, and discontinuation of these programs cause insufficient data. Recent studies conclusively demonstrate that nationwide analysis provide better incidence values and adoption to the risk group selections [21]. Therefore, our study evaluated the most recent data to identify the demographics, incidence, prevalence, and surgery rates of scoliosis in a nationwide perspective, including all categories, within the population.

A recent study from Rochester, Minnesota showed that the incidence of a new diagnosis of scoliosis decreased after discontinuation of school screening programs [21]. According to the same study conducted by Thomas et al., the adolescent growth spurt was particularly prominent in the age groups of 10–15 years for females and 13–15 years for males [21]. In comparison to Thomas et al.'s study, which reported 426.5 new cases per 100,000 individuals per year, 161 new cases were reported per 100,000 from Turkiye. Besides several studies have demonstrated that, notwithstanding some minor discrepancies in prevalence, the overall trend is similar from different continents (Table 1).

According to the school-based screening report from China, an estimated prevalence of AIS between 2920 and 3770 cases per 100,000 individual was reported [4]. Our cohort has less than half of China's estimated numbers, which is 1160 per 100,000 population. The incidence of scoliosis may differ by patient population, genetics, environmental factors, access to healthcare, sex, and age. In contrast with that, scoliosis is more common in girls compared to boys throughout all nations. The frequency of females was found to be 1.45 times greater than that of males in Turkiye ($p < 0.001$). However, female-to-male ratio was reported to be 2.1:1 in USA in 2022.

Table 1 The prevalence rates of various studies based on age group and sex

	Sex	Age	Prevalence (%)
Current Study—Saglam et al. (Turkiye-2023)	F	< 18	1.87
	M		0.31
Ueno et al. (Japan, 2011)	F	11–12	0.78
	M		0.04
	F	13–14	2.51
	M		0.25
Yılmaz et al. (Turkiye-2020)	F	10–15	3.1
	M		1.5
Zhang et al. (China, 1988)	F	7–15	1.2
	M		0.09
Wong et al. (Singapore, 2005)	F	11–12	1.37
	M		0.21
	F	13–14	2.22
	M		0.66
Soucacos et al. (Greece, 1997)	F	< 10	0.2
	M	< 14	0.4
String et al. (England, 1996)	F	9–11	0.4
	M		0.1
	F	12–14	2.2
	M		0.3
Karachalios et al. (Greece, 1999)	F and M	8–16	1.18

Hong Kong researchers evaluated 394,301 students enrolled in 5th grade from 1995–2000. For curves > 10°, prevalence rose from 2.3% in 1995 to 4.7% in 2000 [22]. Similarly, the incidence of scoliosis increased from 107

patients per 100,000 in 2015 to 161 per 100,000 in 2022 in Turkiye. Thus, it may be related to the development of healthcare conditions, the improvement of school screening programs, or increased referrals in Turkiye by the time.

The incidence of recommendation for fusion surgery for scoliosis at initial visit was reported to be between 1.1 and 2.9 cases per 100,000 by some recent studies [1, 21]. Our database showed a slightly higher rate with 3.8 surgical intervention per 100,000 diagnosed patients. Further analysis of our data showed that most patients were diagnosed in public tertiary hospitals and universities (73.9%) and private hospitals and clinics (20.3%), which have more spine referral practice than the general hospitals and primary care centers. This difference probably arose from the high incidence of diagnoses in referral centers resulted with more frequent surgeries in our practice. Although the majority of this cohort consisted of patients requiring non-surgical follow-up, the number of physicians performing spine surgery has also increased over the years due to the increase in the requirement of surgical interventions.

The surgical incidence for scoliosis is reported to be higher in females for all types of scoliosis [21, 23]. Also, in this cohort, 65.7% of all surgical procedures were performed in females. Expectedly, posterior fusion is the most common surgical approach among the surgical preferences in our cohort ($n = 10.111$; 97%) and among most of the studies in the literature [1, 5, 6, 23].

Kwan et al. reported 1.5% overall complication rate including SSI, new neurological deficit, and implant-related complications after surgery for AIS [24]. In contrast with that, Sharma et al. reported almost 60% overall complication including pulmonary problems, implant complications, infections, neurologic deficit, and pseudarthrosis after surgery for neuromuscular scoliosis (NMS) [25]. Patient and surgery-related differences severely influences the complication rates in scoliosis surgery. Our cohort includes all forms of scoliosis such as early-onset, AIS, and NMS. The number of complications related to surgical treatment showed an increasing trend until 2019 but remained steady following years with an 13.4% overall rate through the inspection period.

There are several limitations to our study. It was impossible that these patients were followed clinically and radiographically, and it was never deemed necessary to see an orthopedic surgeon for evaluation. This could also indicate that radiographs were not taken due to only mild findings on physical exam, and that the majority of these patients had only spinal asymmetry. This group could include a large number of children who had curves slightly over 10°, which has no role in clinical practice.

The digital transition of personal health records in Turkiye in 2015 represents a significant milestone, which likely enhanced the accuracy and comprehensiveness of our data. However, potential inaccuracies inherent to the digital records and biases in data collection should be acknowledged. Despite these limitations, our study offers valuable insights into the incidence, demographics, and surgical treatment rates of scoliosis in Turkiye. The notable increase in scoliosis incidence raises important questions about potential changes in risk factors and warrants further investigation. Our findings underscore the need for continued surveillance and targeted interventions, particularly among high-risk groups such as females and individuals in western provinces. They also suggest that improving access to healthcare services in eastern provinces could help detect and manage more cases. The relatively high surgical intervention rate highlights the importance of exploring factors influencing treatment decisions and assessing the effectiveness of these treatments in the Turkish context.

Conclusion

In summary, our study reveals a significant increase in the average incidence of scoliosis diagnosis, rising from 107 per 100,000 individuals in 2015 to 161 per 100,000 in 2022. Scoliosis now impacts an estimated 1.2% of children and adolescents in Turkiye. The risk is 1.45 times higher in females than in males. Western provinces recorded higher incidences across all age groups, likely attributable to the presence of more developed healthcare facilities. Nevertheless, the distribution of age at diagnosis remained consistent across the country. Surgical treatment was pursued in 3.8% of all diagnosed cases. These findings provide a comprehensive perspective on the demographic characteristics, incidence, and surgical treatment rates of scoliosis, offering crucial data for more effective management of the condition.

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Author contributions YS, NEY, and ED performed the design of the study, statistical analysis, development of checklists, interpretation of data, writing of the article, drafting and revision of the article. YS and IB: did acquisition of data and co-writing of the article. NA, MMÜ, SB contributed to the acquisition and analysis of the data. YS, OA, BG, and GÖ contributed to the interpretation of the data and design of the research. All authors critically revised the manuscript, agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

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Declarations

Conflict of interest The authors declare that they have no competing interests.

Ethics approval This study was conducted according to the Declaration of Helsinki and received approval from the Turkish Ministry of Health with a waiver of informed consent for retrospective data analysis and health information privacy law. (ID;95741342-020/27112019).

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