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Original research article
DOI: https://doi.org/10.20544/uklop.2026.617
Received: 24.11.2025 • Accepted after revision: 09.01.2026 • Published: 08.05.2026

#UKLO Annual International Scientific Conference

ADOLESCENT IDIOPATHIC SCOLIOSIS IN HIGH SCHOOL YOUTH IN MACEDONIA AND PUBLIC HEALTH

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Introduction: *Idiopathic scoliosis is a three-dimensional deformity of the spine with an unknown aetiology. Adolescent idiopathic scoliosis is a common disease with an overall prevalence of 0.47–5.2 % in the current literature. The female to male ratio ranges from 1.5:1 to 3:1 and increases substantially with increasing age.*
Method: *Descriptive study of the incident type, which includes 690 children of secondary school age from 15 to 18 years, with a clinical diagnosis of scoliosis, with the goal of radiological confirmation of the condition*
Results: *From the statistical analysis of a total of 690 respondents, high school students aged 15 to 18, determined that spinal deviation is present in all 690 respondents because they come with a referral diagnosis of scoliosis determined by clinical examination. The mild form of scoliosis dominating, which is present in 89.1%, i.e. 614 respondents, with a moderate degree of scoliosis 7.9%, i.e. 54.5 respondents, while the severe form of scoliosis is found in 3%. Scoliosis is more prevalent in female children, i.e. it is present in 65.8% of them compared to male children. In terms of age group, scoliosis is more prevalent in children aged 16-17 years compared to the rest by 1.3%. Kyphoscoliosis as a deformity is present in 41.3% of the respondents, it is more prevalent in the male population.*
Discussion: *Multidisciplinary and multisectoral approach is very important, it includes not only health workers and collaborators and education as a whole, but also the entire community should actively participate in the implementation of health promotion, with the goal of realizing the commitments of the WHO Declaration Health for all.*

Key words: adolescent idiopathic scoliosis, high school youth, radiology, screening, multidisciplinary approach

INTRODUCTION

In medical term, according to SRS (Scoliosis Research Society) scoliosis is defined as condition of side-to-side spinal curves that measure angle is greater than 10º. On an x-ray, the spine of a person with scoliosis looks more like an "S" or a "C" than a straight line. Although curvature of the spine is normal, scoliosis involves and sideways deviation and often includes

a rotational component, in which the vertebral bodies torsion along the spine axis (Addai D et all, 2020).

The human spine is a remarkable structure, balancing **flexibility and stability** to support posture, movement, and load transmission. Its structure is organized into **seven cervical, twelve thoracic,** and**five lumbar vertebrae,** followed by the fused**sacral** and**coccygeal**segments. The stability of the vertebral column arises from its **three-column architecture**, which provides both structural integrity and biomechanical resilience. The **anterior column** comprises the anterior longitudinal ligament and the anterior portion of the vertebral bodies; the **middle column** consists of the posterior wall of the vertebral body and the posterior longitudinal ligament; and the **posterior column** is formed by the posterior bony elements, including the transverse processes, articular facets, laminae, and spinous processes.

Each vertebra permits **six degrees of freedom** - three translational and three rotational - enabling complex spinal movements such as flexion, extension, lateral bending, and rotation. However, the range of motion is not uniform throughout the vertebral column; it varies according to regional anatomical specialization and biomechanical demands. Ultimately, the function of the spine reflects its structural design, demonstrating an intricate adaptation that balances mobility with stability to support posture, movement, and load transmission (Jor Spine, 2020).

Adolescent idiopathic scoliosis is with an unknown etiology. Approximately 30% of individuals with AIS have a family history of scoliosis.

Changes in the spinal column in scoliosis can be expressed as regular curvatures (deviations) of the axis in one plane or as curvatures combined with torsion of the vertebral bodies and rotation in the spine. (Filipović V.2003)

In relation to the age at which they occur, scoliosis is divided into: - infantile, occurring from 0 - 3 years of life, detected most often in the 1st year and manifesting as left thoracic curvature in the largest number of cases; - juvenile, occurring at the age of 4-9 years, most often detected around the age of 6, and manifested as right thoracic curvature; - adolescent, occurs most often between 10 - 14 years, that is, during the period of maturation of the skeletal structure. In most of the cases, 80%, it is present in the deviation and is most often manifested as right thoracic curvature, with localization from TH4/6 or TH11/12—L1. (Hitesh N et all, 2009)

In relation to the skeletal structure, scoliosis is divided into: functional (reducible) and structural (irreparable). Structural scoliosis, on the other hand, can be: congenital and acquired. (Adams J.C.,Hamllen D.L.,2001)

Acquired scoliosis is those that occur during life. In the largest number of cases (60-80%), the cause is unknown, so they are labeled as idiopathic. They occur during growth and worsen later.

According to the localization, according to Ponseti and Friedman (Ponseti I.V., 2003)), these are: lumbar, which occurs in around 24% of cases; thoracic, which occurs in around 22% of cases; cervicothoracic, which occurs in 0.5 - 1% of cases and combined, which occurs in around 37% of cases.

The prevalence decreases significantly as the severity of the curve increases. Curves measuring 10° to 20°: Female-to-male ratio is around 1.4:1. Curves measuring >40°. Prevalence is about 0.1%, and the female-to-male ratio is substantially higher at 7.2:1.

When children have a lateral curvature in the standing position, and in the lying position it is lost, it is not a true scoliosis, but a functional curvature of the spine or an irregular posture. On the contrary, this true scoliosis is always followed by structural changes in the spine and intervertebral discs.

Symptoms of scoliosis may include: noticeable changes in posture, asymetrical shoulders, one shoulder blade appearing more prominent than the other, an uneven waistline, one hip positioned higher than the other, one side of the rib cage protruding forward (Zaina F.et all., 2023) In most cases, scoliosis involves not only a sideways curvature of the spine but also a **rotation or twisting** of the vertebrae. This combined movement causes the ribs or muscles on one side of the body to extend farther outward than those on the opposite side.

When scoliosis is diagnosed, several factors need to be evaluated to determine the most appropriate treatment approach. One of the first considerations is spinal maturity, which indicates whether the patient's spine is still growing and changing. The degree and extent of the curvature are also important, as they show how severe the curve is and how it affects the individual's daily life. The location of the curve plays a role as well—thoracic curves, for instance, are believed by some experts to have a higher likelihood of progressing compared to curves in other spinal regions. Another key factor is the possibility of curve progression, since patients who develop larger curves before adolescent period are at greater risk of worsening deformity.

To confirm the diagnosis and assess these factors accurately, radiographic imaging is essential. X-rays are commonly used to visualize the vertebrae and joint outlines, helping identify other potential causes of pain such as infections, fractures, or deformities. Different imaging modalities have specific roles and indications in the assessment and management of adolescent idiopathic scoliosis (AIS). Radiography remains the gold standard for evaluating and monitoring scoliosis curves. Current guidelines emphasize minimizing the number of radiographs and limiting radiation exposure to the area of clinical interest. (Santiago FR, Ramos – Bossini AJL., Wang YXJ., Zuniga DL., 2020)

Today, the EOS® system represents an essential tool in modern scoliosis management, combining high diagnostic precision with a strong focus on patient safety through substantial radiation dose reduction. As a low-dose, bi-planar X-ray technology, EOS® captures full-body images in a natural, upright, weight-bearing position, allowing for accurate assessment of spinal alignment under physiological load. Its ultra-sensitive detector significantly decreases radiation exposure while maintaining excellent image quality. (Ilharreborde, B.2019)

The system is particularly valuable for the evaluation and longitudinal monitoring of scoliosis and other spinal deformities. Its markedly reduced radiation dose makes it especially suitable for children and adolescents who require frequent imaging during periods of growth. By providing precise measurements, reproducible imaging, and improved safety, the EOS® system has become a cornerstone of contemporary scoliosis assessment and follow-up care.

Three-dimensional (3D) ultrasound is an emerging technology with promising potential, but it remains in the early stages of development and currently has several limitations. Computed tomography (CT), once commonly used in scoliosis assessment, now plays a decreasing role and is being largely replaced by magnetic resonance imaging (MRI), particularly for diagnosis and preoperative planning. (Ng, S.-Y., Bettany-Saltikov, J. (2017)) Computed tomography (CT) scans provide detailed images of the spinal canal and surrounding structures and are particularly effective for examining bone anatomy. Magnetic resonance imaging (MRI) offers three-dimensional images of the spinal cord, nerve roots, and nearby tissues using strong magnets and computer technology, making it especially useful for detecting nerve compression, degeneration, or structural abnormalities. (Janicki JA, Alman B, 2007)

Magnetic resonance imaging (MRI) is used in the evaluation of scoliosis to obtain detailed images of the spine, including the spinal cord, nerve roots, and surrounding soft tissues, in order to identify or rule out any underlying causes of the curvature. An MRI is typically recommended for patients younger than 10 years, those with atypical or rapidly

progressing curves, or individuals presenting with neurological symptoms such as pain, weakness, or numbness. **(**McDonald, S. M., Teh, J. L. 2013)

While X-rays are essential for visualizing bone alignment and measuring spinal curvature, MRI offers a more comprehensive assessment of potential neural abnormalities, including conditions like syringomyelia or tethered cord syndrome, which may contribute to or mimic scoliosis.

Scoliosis management is determined by several key factors, including the patient's age, curve magnitude, and rate of progression. Treatment options range from conservative observation to complex surgical correction, with the primary objectives of preventing curve progression, alleviating symptoms, and optimizing spinal alignment and function. Non-surgical options include bracing to stop curve progression, physical therapy and exercises to relieve pain, and pain management with medication or injections. Surgery is reserved for more severe cases and involves fusing the spine to correct the curve. (Janicki, J. A., Alman, B., 2007)

Idiopathic scoliosis is a three-dimensional deformity of the spine with an unknown etiology. If left untreated, scoliosis can lead to progressive deformity, which may cause back pain, lumbar radiculopathy, cosmetic concerns, nerve injury, and even cardiac or pulmonary restriction. Patients with spinal curves exceeding 80 degrees in the coronal plane are at increased risk of developing shortness of breath. (Le Berre M et all, 2019)

Although surgical complication rates are generally lower than those seen in adult spinal deformity surgery, they still occur. A national dataset reported postoperative neurological injury in 0.9% of cases, respiratory complications in 2.8%, cardiac complications in 0.8%, infections in 0.5%, and gastrointestinal complications in 2.7%. Delayed infections involving surgical hardware are also relatively common. (Lonstein JE., 2018)

Globally, the prevalence of scoliosis varies from 0.11–5.2%, which can be attributed to diverse population characteristics, geographical influences, and etiological factors. Adolescence and female sex have been identified as important risk factors for scoliosis. The female to male ratio ranges from 1.5:1 to 3:1 and increases substantially with increasing age. (Zou Y et all.2022) Other factors such as body mass index (BMI), race, and lifestyle have also been linked to variations in scoliosis prevalence.(Li M. et all, 2024)

In the general population of children in the USA, scoliosis is represented by 1.5% where the angle of curvature is greater than 10 degrees. At female children scoliosis is 5 times more common. Scoliosis with lateral curvature of the spine greater than 10 degrees affects 500,000 adults in the USA (2 - 3%). Idiopathic scoliosis accounts for 65% of the total incidence of scoliosis. (Bollini G, Jouve J.L, Lecoq C, Garron E.,1999)

Research conducted in Europe and worldwide reports a prevalence of adolescent idiopathic scoliosis (AIS) ranging from 0.5% to 5.2%. However, these rates may vary depending on the screening methods used and the age groups included in the studies.(Wang S. et all, 2025)

Low back pain in adults is largely caused by late detected and untreated scoliosis, the prevalence of which is steadily increasing and worsened by lifestyle and work. In one study made in Germany, (Ploumis A., Transfledt E.E.,Denis F.,2006), it was determined that 60% of the causes of lower back pain in adults are scoliosis with a Cobb angle of 23 - 54 degrees, and in 10% when the angle is 45 - 63 degrees.

In Macedonia, according to data from systematic examinations of students in secondary schools in the 2022/23 academic year. (Stambolieva V., Tahiri J.2023) Spinal deformities are monitored in 14.1% (2330) of a total of 16524 examined students aged 15-18. (Figure 1, Source: IPH 2022/2023) That is, they are in first place in terms of the total number of determined pathological conditions. The total number of examined students in the next

2023/24 (Stambolieva V., 2024) with a systematic examination in secondary schools is 16574 students. (Figure 2, Source: IPH 2023/2024) Scoliosis is the most common health problem in this school year, recorded in 12.4% (2057) of the total examined. Compared to the data from primary schools from the same period, a higher incidence is observed in the high school population compared to the school population.

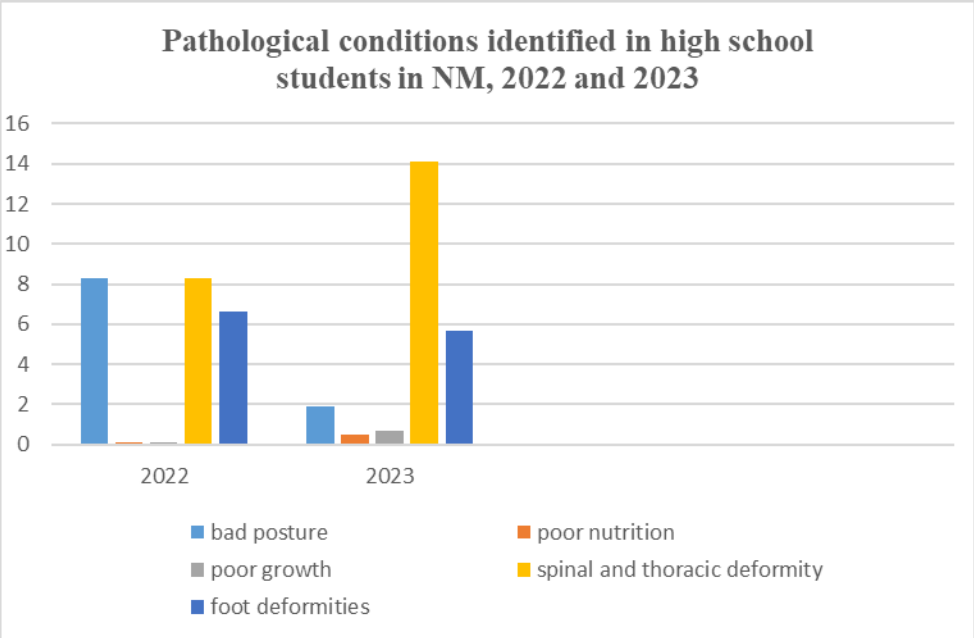

Figure 1. Pathological conditions identified in high school students in NM, 2022 and 2023 (Source: https://iph.mk/mk)

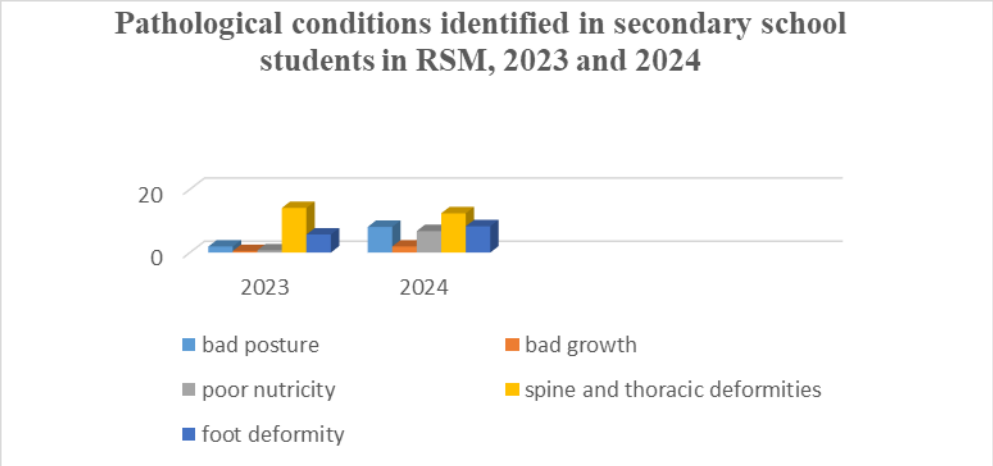

Figure 2. Pathological conditions identified in high school students in NM, 2023 and 2024 (Source: https://iph.mk/mk)

MATERIALS AND METHODS

The aim of this research is to determine radiologically diagnosed AIS in the high school population in the Republic of Macedonia, not only in terms of localization and size of the angle, but also to determine demographically in terms of age, gender, etc.

By design, this is a descriptive study. It was conducted at the Institute of Radiology - Skopje, using data from the electronic repository for performed examinations PACS system, over a period of one year. Our study included a total of 690 subjects, aged 15 to 18 years, with a clinical examination and diagnosis of scoliosis, which was confirmed in all subjects

through X-ray and MRI examinations. Radiological analysis is based on the measurement of Cobb's angle, which is done manually in our institution. Measurements of these angles are easily performed on plain X-ray radiographs. However, the situation is more complicated when these measurements have to be performed on MRI examinations.

The **Cobb angle** is the standard method used to measure the magnitude of a spinal curve. Originally developed for assessing curves in the frontal (coronal) plane, it can also be applied to sagittal plane deformities such as kyphosis and lordosis. (Figure 3, Source: Scoliosis X ray)

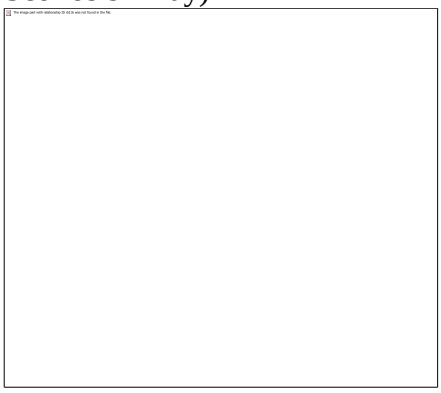

Figure 3.The Cobb method of angle measurement (Source: Scoliosis X ray)

When evaluating scoliosis, radiographs should ideally capture the entire spine on a single **posterior-anterior (P-A)** film to minimize radiation exposure to the chest, particularly the breasts. Even if only a coronal curvature is suspected, a **lateral film** is necessary to assess spinal rotation and sagittal alignment. Whenever possible, imaging should be performed in a **standing position** to reflect the spine's natural load-bearing posture; if standing is not possible, sitting is preferred over a supine position. For the P-A view, the arms should rest at the sides, while for the lateral view, they should be abducted 90 degrees to prevent obstruction of the spinal column. Although shielding of the pelvic area is common, **initial films should be taken without gonadal shields** to allow full visualization of the hips, pelvis, and proximal femurs. To **measure the Cobb angle**, the examiner first identifies the **upper and lower end vertebrae**—the most tilted vertebrae at the top and bottom of the curve that incline toward its concavity. The curve is classified according to the location of its **apex (vertex)** as thoracic, thoracolumbar, or lumbar. A line is then drawn parallel to the **superior endplate** of the upper end vertebra and another parallel to the **inferior endplate** of the lower end vertebra. Since these lines often do not intersect within the image, perpendicular lines (90°) are drawn from each. The **Cobb angle** is defined as the angle formed where these perpendiculars intersect - representing the degree of spinal curvature.

RESULTS

From the statistical analysis of data processing from a total of 690 respondents, high school students aged 15 to 18, It was determined that spinal deviation is present in all 690 respondents because they come with a referral diagnosis of scoliosis determined by clinical examination, with the mild form of scoliosis dominating, which is present in 89.1%, i.e. 614 respondents, with a moderate degree of scoliosis 7.9%, i.e. 54.5 respondents, while the severe form of scoliosis is found in 20.7 respondents, i.e. 3%. (Figure 4)

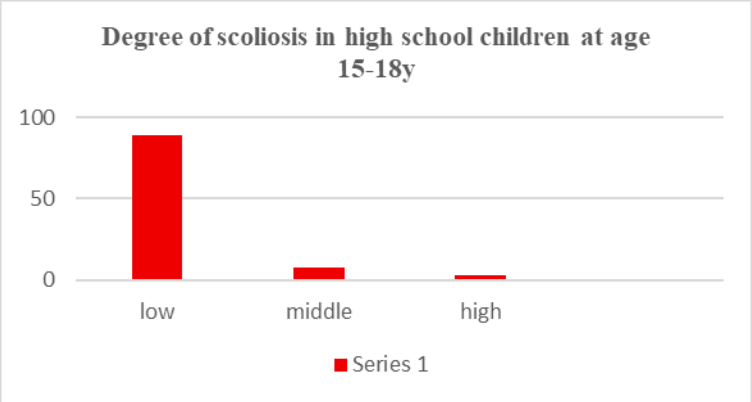

Figure 4. Degree of scoliosis in high school youth (Souce: Own depiction)

The gender structure of the respondents is represented by 38.4% male, i.e. 265, and 61.6% female, i.e. 425. (Figure 5)

Figure 5. Gender distribution and scoliosis in high school youth (Souce: Own depiction)

In terms of the side of the deviation, bilateral scoliosis is more common, occurring in 61.1% of the respondents, i.e. a total of 421.5 respondents. (Figure 6)

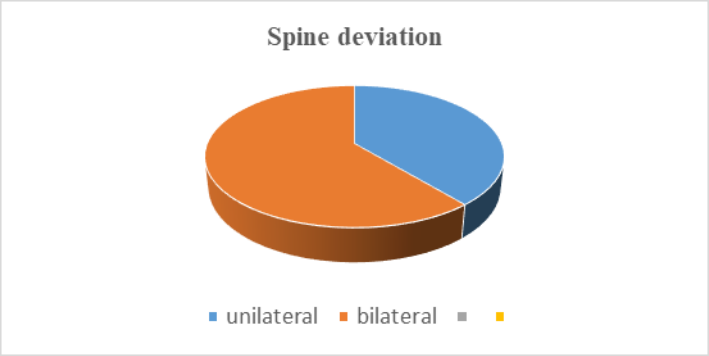

Figure 6. Spine deviation in school youth (Souce: Own depiction)

About localization, it most often affects the thoracolumbar part of the spine, occurring in 65.7% , followed by lumbar scoliosis, occurring in 26.1%, and the smallest percentage falls on thoracic scoliosis, i.e. 8.2% . (Figure 7)

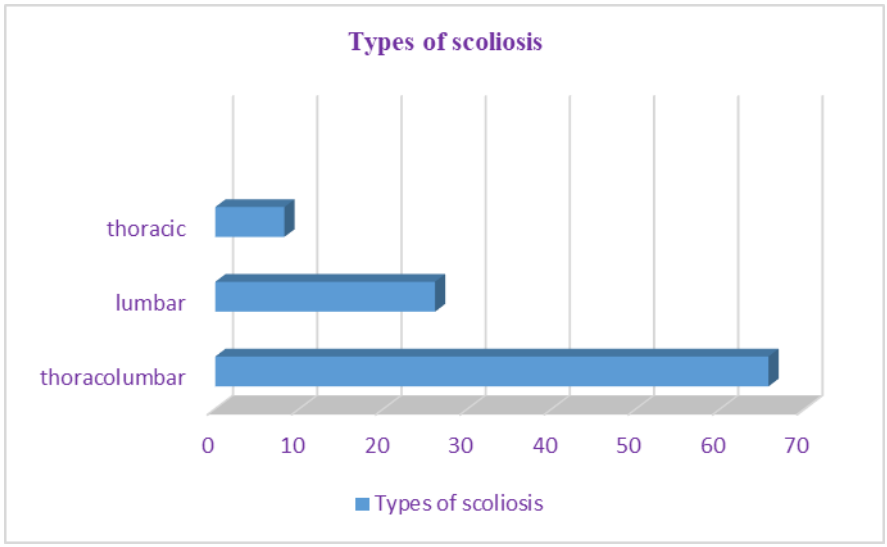

Figure 7. Types of scoliosis in high school youth (Souce: Own depiction)

The angle of curvature of the spine ranges from 10-78 degrees with an average value of 18.1+-8.9 degrees. (Tab 1)

Tab 1. Descriptive statistics of angle (Souce: Own depiction)

Parametars	Valid N	Mean	Minimum	Maximum	Std dev
Angle of deviation	690	18,1	10	78	8.9

Scoliosis is more prevalent in female children, i.e. it is present in 65.8% of them compared to male children. In terms of age group, scoliosis is more prevalent in children aged 16-17 years compared to the rest by 1.3%.

In relation to age groups, gender distribution and representation of scoliosis, in the youngest age group there are 142 female children against 63 male children. In the midle age group, there are 196 female children against 63 male children. And in the oldest group from 17 – 18 years old, there are 116 female children against 78 male children. (Figure 8)

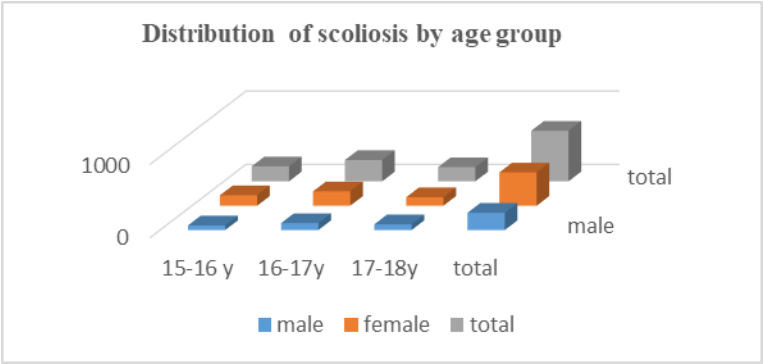

Figure 8. Distribution of scoliosis by age group (Souce: Own depiction)

Kyphoscoliosis as a deformity is present in 41.3% of the respondents, it is more prevalent in the male population. Ratio between male and female children and kyphoscoliosis in our study is 1,96:1. (Figure 9)

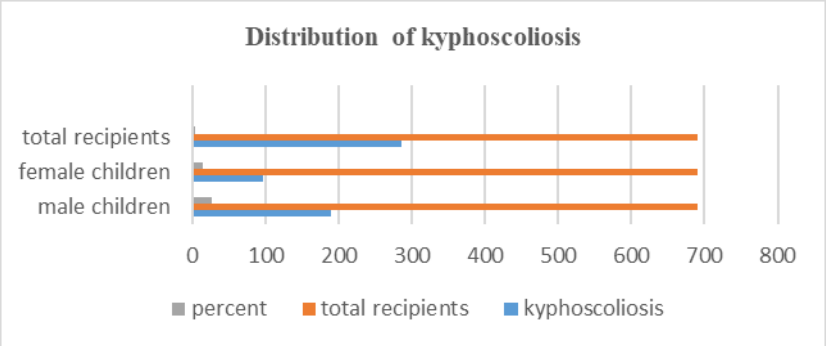

Figure 9. Distribution of kyphoscoliosis by gender (Souce: Own depiction)

The distribution of the respondents and the imaging technique that was carried out for the diagnosis of scoliosis, there are 239 male children and 277 female children on x-ray, or a total of 516 compared to 174 conducted on magnetic resonance, of which 85 male children and 89 are female children. (Figure 10)

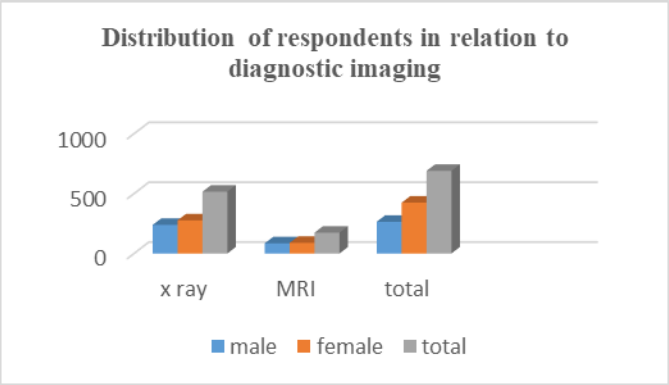

Figure 10. Distribution of respondents in relation to diagnostic imaging (Souce: Own depiction)

DISCUSSION

The results of this research showed that the prevalence of scoliosis is significantly higher in our country compared to developed countries. Distribution by gender and age shows that scoliosis is more prevalent in the female population and in the age group of 16 - 17 years. The results related to the types of scoliosis, the size of the angle and the location of the deviation confirmed that the most common is mild scoliosis, with an angle of less than 20 degrees and a thoracolumbar deviation, data that are more or less similar to those in published studies from different countries in the world.

The study by Daruwalla was carried out in Singapore and involved 110,744 children (60,167 girls and 50,577 boys). Children from 6 to 18 years old are included, but in the group that corresponds to our age population, only female children between the ages of 16 and 17 years old are included, and the prevalence of AIS is 3.12%. (Daruwala JS et all.1985)

Most studies of scoliosis in children and adolescents identify several factors that contribute to its high incidence and prevalence. These include **genetic predisposition, body mass index (BMI), insufficient physical activity, age, and the use of inappropriate school furniture**, among others. Some researches suggest that participation in asymmetrical sports - such as gymnastics, handball, and tennis - may increase the incidence of AIS.

However, modern lifestyles have greatly increased the risk of spinal problems. Prolonged use of smartphones and tablets encourages extended sitting and improper posture,

which in turn contributes to a growing number of spinal deformities among children. Therefore, the development of healthy lifestyle habits should start within the family, the cornerstone of society and be further reinforced through education and school-based programs.

Screening is a technique that has been popularized in the past few decades and is implemented in almost all developed and highly developed countries in the world. It is based on the use of tests with adequate sensitivity and specificity in terms of early detection of scoliosis and ensuring proper treatment of patients.

Untreated idiopathic scoliosis may lead to trunk deformities that compromise body aesthetics, reduce chest wall mobility, and decrease physical capacity.(Mackel C.E. et all., 2018) Therefore, early detection of idiopathic scoliosis is crucial as it can minimise the risk of idiopathic scoliosis progression, and can eliminate the need for surgical treatment.(Czaprowski D et all.2025)

The cost-benefit of screening is great, and the costs are low compared to the results that are achieved. The effectiveness of screening is also increased by the fact of increased awareness among children about this disease and easier acceptance of treatment methods. **School age** represents an optimal period to educate children about the importance of **healthy nutrition, physical activity, and overall well-being**. During this stage, children actively engage in social environments and increasingly shape their own lifestyle behaviors. A **varied and nutritionally balanced diet** supports growth and development, while **daily physical activity** contributes to psychomotor development, energy balance, and overall health. Early initiation of health education benefits not only the individual child but also the family and society, fostering lifelong healthy habits. Effective prevention requires commitment, resources, and effort, but its benefits are substantial. Crucially, **early detection of health risks** is a key component of preventive strategies, improving the likelihood of positive outcomes for both minor and chronic conditions.

In the context of **adolescent idiopathic scoliosis (AIS),** early detection and screening are critical preventive strategies. The **United States Preventive Services Task Force (USPSTF)** initially recommended routine screening for AIS in 1986, advising screening **twice annually in girls aged 10–12 years** and **once annually in boys aged 13–14 years**. Early identification in premenarchal girls was reported to **reduce the risk of curve progression by 20–30%** (USPSTF, 1996). Following evidence reviews, the USPSTF updated its 2018 recommendation, concluding that current evidence is **insufficient to assess the balance of benefits and harms** of routine screening in asymptomatic adolescents. While early detection may facilitate non-surgical interventions such as bracing, screening may also result in overdiagnosis, unnecessary imaging, and psychosocial stress. Clinicians are therefore encouraged to apply individualized judgment when considering AIS screening (USPSTF, 2018).

CONCLUSION

Technological advances in **diagnostic imaging, EOS imaging system,** have further enhanced scoliosis management. Collectively, these approaches demonstrate that **effective health promotion, early detection, and appropriate technological support** are integral to optimizing child and adolescent health. By combining **school-based education, preventive screening, and advanced imaging**, it is possible to foster lifelong healthy behaviors while minimizing the risks and consequences of common pediatric conditions, such as scoliosis.

Also, the continuous education and professional development of educational staff constitute a fundamental advantage for all students, irrespective of gender or age. Within this

framework, the adoption of a multidisciplinary and multisectorial approach is essential - one that encompasses not only health professionals and educators but also active involvement from the wider community. Such collective engagement is crucial for the effective implementation of health promotion strategies, ultimately contributing to the realization of the commitments articulated in the World Health Organization's *Health for All* Declaration.

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