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REVIEW ARTICLE

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Nutritional aspects and waiting time for surgery in cobb angle worsening in young patients with scoliosis: a systematic review

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Abstract

Introduction: The prevalence of scoliosis varies geographically and ethnically, and it is most frequently diagnosed in adolescence, typically between the ages of 10 and 18. The impact of the use of calcium and vitamin D in patients with idiopathic scoliosis appears to be promising, reducing the incidence and prevalence of cases. Studies on the natural progression of scoliosis indicate that untreated patients may experience significant worsening of the condition. **Objective:** It was to analyze the nutritional aspects and waiting time in Cobb Angle worsening in young patients with scoliosis. **Methods:** The PRISMA systematic review guidelines were followed. Randomized clinical trials, prospective studies, and retrospective studies were included in the analysis. The literature search was conducted from January to March 2026 and was based on Web of Science, Scopus, Embase, PubMed, Lilacs, Ebsco, Scielo, and Google Scholar, covering scientific articles from various periods to the present. **Results and Conclusion:** A total of 119 articles were submitted to eligibility analysis, with 18 final studies selected with 3,778 participants selected for this systematic review (scoliosis and nutritional deficiency, n=07, and scoliosis, waiting times, and the progression of Cobb angle, n=11). According to the GRADE instrument, most studies for scoliosis and nutritional deficiency showed homogeneity in their results, with X^2=77.1%>50%, and X^2=68.4>50% for scoliosis, waiting times, and the progression of Cobb angle. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 25 studies with a high risk of bias and 22 studies that did not meet the GRADE and AMSTAR-2 criteria. Figures 2 and 3 present the results of the risk of bias of the studies with symmetrical behavior, suggesting a low risk of bias. It was concluded that patients undergoing scoliosis surgery experience prolonged waiting times, which may contribute to the progression of the deformity, including an increase in the Cobb angle. Strategies to reduce this waiting time may lead to improved clinical outcomes and fewer complications. Studies show that individuals on the waiting list for adolescent idiopathic scoliosis surgery experience worsening of the spinal deformity, increased treatment costs, and may negatively impact patients' quality of life. Increased waiting times for surgery negatively impact the quality of life of scoliosis patients. The positive correlation between vitamin D and calcium, together with the negative correlation with the Cobb angle, is further proof that patients with idiopathic scoliosis should be regularly investigated for these pathologies.

Keywords: Scoliosis. Scoliosis Surgery. Cobb Angle. Complications. Nutrition. Nutrology.

Introduction

The prevalence of scoliosis varies geographically and ethnically, and it is most frequently diagnosed in adolescence, typically between the ages of 10 and 18

[1]. Scoliosis is an orthopedic condition that causes a three-dimensional deformity of the spine. This can significantly impact patients' quality of life, causing chronic pain, functional limitations, and, in severe cases, respiratory and cardiovascular complications **[1,2]**. Surgical treatment is indicated for severe cases, aiming to correct spinal misalignment. Studies indicate that if scoliosis progresses untreated, it can result in pulmonary and cardiovascular complications **[3-6]**. In Brazil, the Unified Health System (SUS) plays a crucial role in caring for these patients **[7]**.

In this scenario, idiopathic scoliosis affects a large number of children, compromising their quality of life and development. From this perspective, the impact of using calcium and vitamin D in patients with idiopathic scoliosis seems promising, reducing the incidence and prevalence of cases **[8-10]**. Nutritional status, combined with physical activity, may explain the worsening of idiopathic scoliosis in adolescents. Studies have shown that patients with idiopathic scoliosis have lower vitamin D levels than controls and that most patients have insufficient or deficient serum vitamin D levels. Lower concentrations of parathyroid hormone and calcitonin have also been found in patients with idiopathic scoliosis compared to controls, as well as trace element abnormalities. In studies that assessed physical activity, three found that girls with idiopathic scoliosis were less active than controls **[10]**.

Diagnosis can be difficult and is often incidental at a young age. Choosing the best treatment is important to consider the patient's age, etiology, and rate of progression. Among non-operative treatments, the most effective are the use of serial casts or orthoses, the primary goal of which is to halt the progression of the deformity and thus delay surgical treatment. Among surgical treatments, distraction-based systems and definitive arthrodesis have proven to be the most effective. Early surgery leads to multiple complications, which is why, if feasible, non-surgical treatment should be pursued and fusion postponed until skeletal maturity. Due to the life-threatening risks associated with the deformity and treatment, it is important to educate the patient and family members about the importance of adherence to treatment and follow-up **[11,12]**.

The progression of scoliosis, from diagnosis to surgical intervention, can be complex and requires ongoing monitoring. Studies on the natural progression of scoliosis indicate that untreated patients may experience significant worsening of the condition, especially in patients with nutritional deficiencies, with complications such as deterioration of lung function and even an increased risk of death **[4,5]**. In contrast, surgical treatment is effective in correcting the Cobb angle and improving quality of life, although there may be complications associated with the procedure and the length of time patients wait for surgery **[13,14]**.

Therefore, the present study aimed to analyze the nutritional aspects and waiting time in Cobb Angle worsening in young patients with scoliosis.

Methods

Registration in PROSPERO

This systematic review study was duly registered in the *International Prospective Register of Systematic Reviews*: PROSPERO 2026CRD420261338040. Available from https://www.crd.york.ac.uk/PROSPERO/view/CRD420261338040.

Study Design

This study followed an international systematic review model, following the PRISMA (preferred reporting items for systematic reviews and meta-analysis) guidelines. Available at: http://www.prisma-statement.org/?AspxAutoDetectCookieSupport=1. Accessed on: 01/22/2026. The methodological quality standards of AMSTAR-2 (Assessing the methodological quality of systematic reviews) were also followed. Available at: https://amstar.ca/. Accessed on: 01/22/2026.

Settings

Based on experience in hospitals in Brazil, the main factors that helped define the inclusion and exclusion criteria were: - High incidence of Cobb Angle worsening in young patients and those with nutritional deficiencies; - Patients who experienced an increased time to undergo scoliosis surgery; Thus, this systematic review study aimed to analyze whether this reality also exists and what the odds ratio of these aforementioned relationships is in published studies from different hospitals around the world.

Research Strategy and Sources

The literature search process was conducted from January to March 2026 and developed based on Web of Science, Scopus, Embase, PubMed, Lilacs, Ebsco, Scielo, and Google Scholar, covering scientific articles from various periods to the present. The following descriptors (DeCS/MeSH Terms) were used: "*Scoliosis. Scoliosis Surgery. Cobb Angle. Complications. Nutrition. Nutrology*", and using the Boolean operator "and" between MeSH terms and "or" between historical findings.

Study Quality and Risk of Bias

Quality was classified as high, moderate, low, or very low regarding the risk of bias, clarity of

comparisons, precision, and consistency of analyses. The most evident highlight was for systematic review articles or meta-analyses of randomized clinical trials, followed by randomized clinical trials. Low-quality evidence was attributed to case reports, editorials, and brief communications, according to the GRADE instrument. GRADE-CERQual (Qualitative Studies Assessment) was used to assess confidence in the findings of qualitative evidence syntheses, based on four components: -Methodological Limitations: Risk of bias in the design of the included studies; -Coherence: Degree to which the studies support the review finding; -Data Adequacy: Quality and quantity of data supporting the finding; - Relevance: Degree to which the data applies to the context of the review question.

The risk of bias was analyzed according to the Cochrane instrument by means of the Funnel Plot analysis (Sample size versus Effect size), using Cohen's d test.

Strategies for Handling Missing

Data Data Collection and Attempt at Retrieval Strategies

Before applying statistical methods, the first approach was to try to obtain the missing data.

- ✓ **Contacting the authors:** Contacting the authors of the original studies is the most recommended approach to obtain raw data or missing information.
- ✓ **Calculation from other data:** Often, missing data (e.g., standard deviation) could be calculated from other information available in the article (e.g., y-values, confidence interval, or sample size).
- ✓

Statistical Treatment Methods

When the data could not be retrieved, statistical techniques were employed:

- ✓ **Complete Case Analysis (CCA):** This involves excluding studies or patients with missing data, analyzing only complete cases. It is simple, but it can reduce the sample size and increase bias.
- ✓ **Single Imputation:** It was replaced the missing value with a single estimated value, such as the mean or median.
- ✓ **Multiple Imputation (MI):** It was created multiple simulated datasets with different plausible values, allowing the uncertainty of missing data to be incorporated into the final estimates. It is considered more robust than single imputation.
- ✓ **Maximum Likelihood-Based Methods:** Sophisticated techniques that use all available information to estimate parameters without directly filling in missing data.
- ✓

Specific Approaches to Systematic Review

- ✓ **Sensitivity Analysis:** Recommended to verify whether missing data influenced the result. It consisted of performing the systematic review in two ways: (1) with the imputed data and (2) with the complete cases, comparing whether the conclusions changed.
- ✓ **Analysis of the Missing Mechanism:** The goal was to determine whether the data are missing at random (MAR), missing completely at random (MCAR), or missing not at random (MNAR), which informed the choice of the most suitable method.

Statistical Analysis

Stata 18 and Minitab 21 software were used to process the data resulting from this study. Cohen's t-test was performed to calculate the effect size, and the inverse standard error (sample size) was used to determine if there was a risk of bias through analysis of the graphical symmetry of the studies in the Funnel Plot. The Heterogeneity Test (Chi-Square Test – X^2) was also performed on the results of the studies, adopting $X^2>50\%$ with homogeneous results between studies, and $p<0.05$ without a statistically significant difference, in the 95% CI. The analyses followed Pearson's Chi-square test, with $p<0.05$ indicating statistical significance of association, with a 95% confidence interval (CI).

Results and Discussion

Summary of Findings

A total of 119 articles were submitted to eligibility analysis, with 18 final studies selected with 3,778 participants were selected for this systematic review (scoliosis and nutritional deficiency, n=07, and scoliosis, waiting times and the progression of Cobb Angle, n=11). The listed studies presented medium to high quality (Figure 1), considering the level of scientific evidence of studies such as meta-analysis, consensus, randomized clinical, prospective, and observational. Biases did not compromise the scientific basis of the studies. According to the GRADE instrument, most studies for scoliosis and nutritional deficiency showed homogeneity in their results, with $X^2=77.1\%>50\%$, and $X^2=68.4>50\%$ for scoliosis, waiting times and the progression of Cobb angle. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 25 studies with a high risk of bias and 22 studies that did not meet the GRADE and AMSTAR-2 criteria.

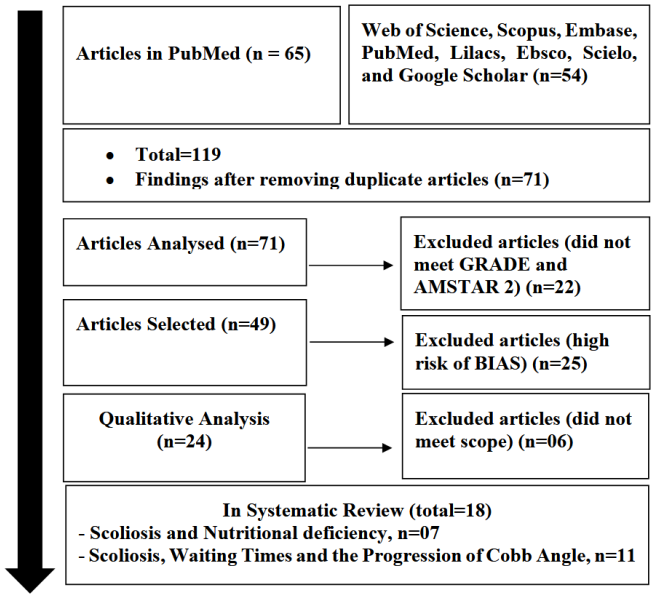

Figure 1. Selection of articles. Source: Own authorship.

Major Findings – Scoliosis and Nutritional Deficiency

Figures 2 and 3 present the results of the risk of bias of the studies using the Funnel Plot, showing the calculation of the Effect Size (Magnitude of the difference) using Cohen's Test (d). The precision (sample size) was determined indirectly by the inverse of the standard error (1/Standard Error). This graph exhibits symmetrical behavior, suggesting a low risk of bias, both in studies with small sample sizes (lower precision) shown at the bottom of the graph and in studies with large sample sizes presented in the upper region.

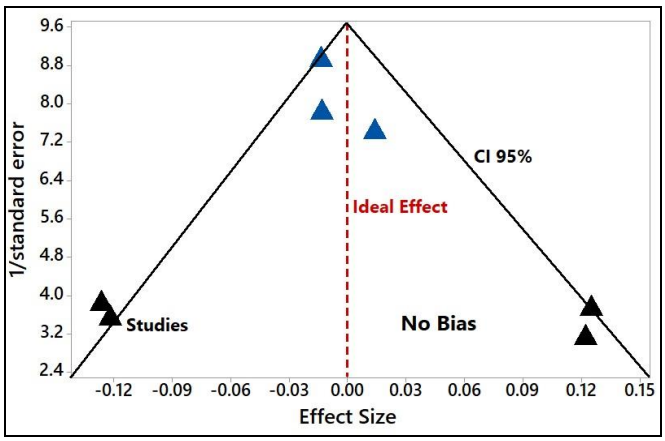

Figure 2. The symmetrical funnel plot does not suggest a risk of bias between the small sample size studies that are shown at the bottom of the graph. High confidence and high recommendation studies are shown above the graph. N=07 studies. Source: Own Authorship.

Herdea et al. (2020) **[15]** analyzed the relationship between 25-OH-vitamin D, total calcium, and the following data: Cobb angle, age, and sex of the patient. A total of 101 patients with a mean age of 11.61±2.33 years had their vitamin D and calcium levels measured. The mean Cobb angle was 26.21°±12.37°. The mean vitamin D level was 24 ng/mL±9.64. Calcium values were within the normal range, with a mean of 9.82 mg/dL±0.42. The male group presented lower vitamin D levels compared to the female group (19.6 vs. 25.45 ng/mL) ($p=0.02$). Seasonal variations showed significant differences for vitamin D ($p=0.0001$). Vitamin D levels showed a positive correlation with calcium levels ($p=0.01$, $r=0.973$), as well as with the patient's age ($p<0.001$, $r=0.158$). The Cobb angle showed a negative correlation with serum vitamin D levels ($p<0.01$, $r=-0.472$).

Furthermore, the authors Mayes et al. (2017) **[16]** showed the vitamin D status in patients with scoliosis in preparation for surgical intervention. A total of 217 patients with a mean age of 13.6 ± 3.6 years had their vitamin D levels measured on average 38.7±20.6 days before surgery. Most of the sample had a diagnosis of idiopathic scoliosis (n=126), and most patients were scheduled for spinal fusion surgery (n=192). Almost 75% of the studied population (n=162) had vitamin D25 levels below normal. African Americans had a higher risk of deficiency ($p<0.0002$) compared to Caucasians, as did patients preparing for spinal fusion versus those undergoing growth rod placement ($p < 0.03$). Patients with neuromuscular scoliosis had significantly higher vitamin D25 levels than those with an idiopathic diagnosis ($p < 0.0002$). Gender, BMI, and age did not influence vitamin D25 levels.

Turner et al. (2023) **[17]** evaluated the change in nutritional status of young patients with early-onset scoliosis after treatment with magnetically controlled growth rod (MHCR) instrumentation at a single center. Exclusion criteria were follow-up of less than 2 years and incomplete weight-for-age Z-score (WAZ) data. A total of 68 (37 men/31 women) were included. The mean age at surgery was 8.2 years (SD 2.8; range 1.8 to 14.2) and the mean follow-up time was 3.8 years (SD 1.0; range 2.1 to 6.8). The study population was categorized by primary diagnosis as follows: 23 neuromuscular patients, 18 idiopathic, 15 congenital, and 12 syndromic. The main coronal curve showed a 40% improvement between the preoperative and final visits ($p<0.005$; SD 27; CI 33-47), while the proportion of available lung space improved by 8% ($p<0.005$; SD 13; CI 5-12). Thoracic height increased by 25% ($p < 0.005$; SD 13; CI 22-28) and the kyphosis angle decreased by 25% ($p < 0.005$; SD 26; CI 9-39). Eighteen patients (27%) required a total of 53 periodic upper revisions. The WAZ improved significantly between preoperative and the last follow-up ($p =$

0.005). Treatment of patients with early-onset scoliosis with MCGR resulted in improved nutritional status, evidenced by the significant increase in WAZ.

In addition, the authors Kiebzak et al. (2019) **[18]** demonstrated through a retrospective observational study the confounding effect of combining subgroup data, specifically race, on the prevalence of vitamin D deficiency in adolescent idiopathic scoliosis. Vitamin D deficiency was defined as 25-hydroxyvitamin D (25**[OH]**D) less than 20 ng/mL. Data were compared between white patients and black and Hispanic patients. The mean age was 13.9±2.3 years for white girls with adolescent idiopathic scoliosis (n=221) and 13.6±2.2 years for the group of non-white girls (n=134). Significant racial differences were found that biased the interpretation of the pooled total cohort. The mean 25(OH)D was 27.9 ± 8.5 ng/mL for white girls with adolescent idiopathic scoliosis (AIS) versus 21.9 ± 10.3 ng/mL for non-white girls ($p<0.0001$). Disability was present in 13.1% of white girls versus 47.8% of non-white girls ($p<0.0001$). The prevalence of disability was higher in non-white girls with AIS than in white girls.

To corroborate these aforementioned findings, a meta-analysis study conducted by the authors Llopis-Ibor et al. (2023) **[19]** analyzed the incidence of vitamin D deficiency in patients with adolescent idiopathic scoliosis. Six studies, with a total of 1,428 patients, met the inclusion criteria. The incidence of vitamin D insufficiency in patients with idiopathic scoliosis was 36.19% (95% CI [21.93 to 50.46]). In contrast, the incidence of vitamin D deficiency was 41.43% (95% CI [16.62 to 66.23]). Vitamin D levels were compared between Caucasian and African patients, and it was concluded that Caucasian patients had a lower risk of vitamin D deficiency [RR 0.15, 95% CI [0.03 to 0.82]; p = 0.03]. There was also an association between patients with idiopathic scoliosis and lower vitamin D levels (-5.58, 95% CI [-7.10 to -4.06]). No significant differences were observed in terms of curve magnitude, assessed by the mean difference (MD) of the Cobb angle (4.45, 95% CI [-0.55 to 9.44]), or between sex and below-normal vitamin D levels (OR 0.96). 95% CI [0.58 to 1.60].

A Mendelian randomization study conducted by the authors Ghanbari et al. (2023) **[20]** investigated causal associations between body composition and puberty-related exposures and the risk of idiopathic scoliosis in European and Asian adolescents. Single-nucleotide polymorphisms (SNPs) associated with body mass index (BMI), waist-to-hip ratio, lean mass, childhood obesity, bone mineral density (BMD), 25-hydroxyvitamin D (25OHD), age at menarche, and pubertal growth were used. The results of inverse variance-weighted Mendelian Randomization (MR) estimates suggest that there is no causal association between the aforementioned risk factors and the risk of ischemic stroke. Restricting the analysis to European women with ischemic stroke, a causal association was observed between estimated bone mineral density (BMD) and the risk of ischemic stroke.

Finally, the authors Danielewicz et al. (2023) **[21]** investigated the concentrations of specific agents related to bone remodeling in post-menarche girls diagnosed with adolescent idiopathic scoliosis. The study included 36 patients with scoliosis and 18 age-matched healthy individuals allocated to the control group. Patients underwent clinical and radiological examinations to assess the degree of spinal deformity, curvature type, and skeletal maturity. The results demonstrated that the balance between calcium-phosphate and parathyroid hormone levels appears normal in adolescent idiopathic scoliosis. Furthermore, no statistically significant differences were observed in the levels of Klotho protein, osteocalcin, osteoprotegerin, C-terminal telopeptide of type I collagen, sclerostin, and alkaline phosphatase. However, serum vitamin D (25-OH-D) levels were reduced, while N-terminal propeptide of type I procollagen and fibroblast growth factor 23 (FGF23) were increased in the adolescent idiopathic scoliosis group.

Major Findings – Scoliosis, Waiting Times and the Progression of Cobb Angle

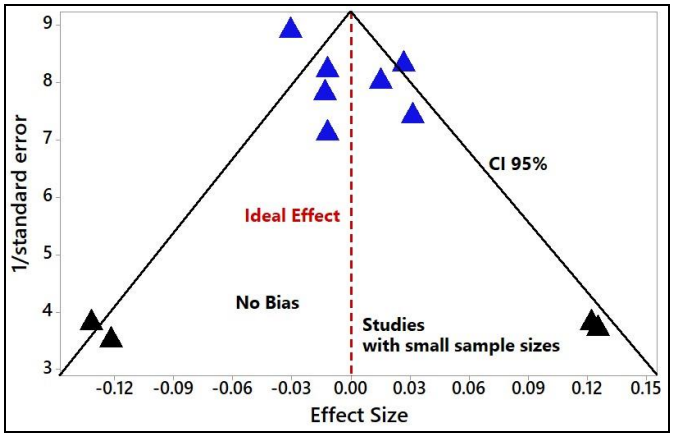

Figure 3. The symmetrical funnel plot does not suggest a risk of bias between the small sample size studies that are shown at the bottom of the graph. High confidence and high recommendation studies are shown above the graph. N=11 studies. Source: Own Authorship.

Previous studies suggest that delays in intervention can lead to worse functional outcomes. Therefore, improvements in access to surgery are essential **[5,6,12-14,23]**. In the context of this study on waiting times and the progression of Cobb angle

deformity in scoliosis, a multicenter retrospective study by Guiroy et al. (2023) **[23]** estimated the time between initial consultation and surgery in patients with adolescent idiopathic scoliosis (AIS). A total of 509 AIS patients from 16 hospitals in six Latin American countries were evaluated. A total of 66.8% of patients waited more than six months, and 33.9% more than a year. Longer time to surgery was significantly associated with an increase in the magnitude of the Cobb angle over the second year of waiting ($p<0.001$). The reported causes for the delay were hospital-related (48.4%), economic (47.3%), and logistical (4.2%).

Pontes et al. (2023) **[24]** developed a systematic review to analyze the impact of waiting time for surgical correction of AIS from the perspective of deformity progression, treatment costs, and quality of life. Six observational studies were included. In a Canadian study, the primary outcome was the need for additional spine surgery in patients who had to wait more than three months due to progression of spinal deformity. American researchers presented a sample of premenarchal and skeletally immature patients with AIS who presented with an increased Cobb angle and attributed this to a six-month wait for surgical treatment. Another study included 177 patients with AIS with a mean wait time of 225.7 days. There was a mean worsening of 7.7° ± 8.6° in the Cobb angle, and there was a change in surgical plan in 28 patients, which increased surgical time. Furthermore, studies have shown significantly higher average costs in those who waited more than six months, and other studies have shown an improvement in quality of life in patients who underwent surgery in a shorter wait time.

Bressan-Neto et al. (2021) **[25]** evaluated the clinical impact of waiting time for surgical treatment of patients with spinal deformities in 59 patients. The radiographic parameters selected for comparison were Cobb angle of the primary and secondary curves, coronal alignment, apical vertebral translation, pelvic obliquity, sagittal vertebral axis, kyphosis (T5-T12), and lordosis (L1-S1). Low health-related quality of life scores were observed in patients awaiting surgery. Radiographic parameters showed progression of the deformity at the initial evaluation compared with the most recent follow-up evaluation.

Calman, Smithers, and Rowan (2013) **[26]** also evaluated whether waiting time for surgery impacts quality of life and surgical outcomes. Patients awaiting or having completed surgery for pediatric spinal deformity in the last 3 years were contacted and asked to complete the Scoliosis Research Society-30 (SRS-30) questionnaire, as well as a questionnaire specifically designed to assess the impact of waiting for surgery. They found that longer waiting times were associated with lower SRS-30 scores (0.13 points per 6 months, $p=0.01$) and lower waiting time questionnaire scores (0.12 points per 6 months, $p<0.01$). Cobb angles progressed with increasing waiting time.

Also, Elmeshneb et al. (2024) **[27]** conducted a systematic review study to analyze the combined rates of postoperative complications and risk factors for complications in neuromuscular scoliosis surgery. A total of 22 studies were selected, with 2,155 patients. The level of evidence among the studies was III (9) and IV (13). The combined incidence rate of surgical wound complications was the highest among all complications, at 13.3%, followed by respiratory complications. Implant failure occurred in 7.1% of cases, gastrointestinal complications were 5.2%, pseudarthrosis in 4.6%, and neurological deficit in 2.9%. The combined rate of revision surgery was 9.6%. Wound-related (13.3%) and respiratory (11.8%) complications remain the most common complications among studies after corrective surgery for neuromuscular scoliosis. In the present study, the most common complication was crankshaft effect, occurring in 57.8%.

Finally, in an attempt to minimize complications of AIS surgery, Oggiano et al. (2025) **[28]** compared the standard open posterior approach (OPA) with the mini-open surgery (MOS) technique in a randomized clinical trial. A total of 60 patients with Lenke type 1 AIS and a single thoracic curvature were randomized to the OPA ($n=30$) or MOS ($n=30$) groups. The MOS technique utilized three midline incisions, a muscle-splitting approach, and selective fusion at instrumented levels. Both groups achieved comparable correction without loss at 2 years (MOS: 79.7% ± 8.0%; OPA: 85.0% ± 7.4%; $p > 0.05$). The MOS group had reduced intraoperative blood loss (383.3 ± 82.9 mL vs. 720.2 ± 74.3 mL; $p = 0.019$), shorter hospital stay (6.2 ± 0.3 vs. 7.4 ± 1.2 days; $p = 0.044$), and lower VAS scores at discharge (2.9 ± 1.8 vs. 3.9 ± 1.4; $p = 0.02$) and 2 years (1.5 ± 0.5 vs. 2.0 ± 0.7; $p = 0.03$). Satisfaction with the scar was higher in the MOS group (4.5 ± 0.3 vs. 2.8 ± 0.6; $p = 0.02$).

Limitations

More randomized clinical trials are needed on the relationship between vitamin D and calcium and scoliosis, as well as on nutrient supplementation in young participants. The international literature presents few randomized clinical trials with significant sample sizes on patient waiting times for scoliosis surgery, as well as measures to mitigate potential Cobb angle progression during the waiting period.

Conclusion

It was concluded that patients undergoing scoliosis surgery experience prolonged waiting times, which may contribute to the progression of the deformity, including an increase in the Cobb angle. Strategies to reduce this waiting time may lead to improved clinical outcomes and fewer complications. Studies show that individuals on the waiting list for adolescent idiopathic scoliosis surgery experience worsening of the spinal deformity, increased treatment costs, and may negatively impact patients' quality of life. Increased waiting times for surgery negatively impact the quality of life of scoliosis patients. The positive correlation between vitamin D and calcium, together with the negative correlation with the Cobb angle, is further proof that patients with idiopathic scoliosis should be regularly investigated for these pathologies.

CRediT

Author contributions: Conceptualization; Data curation; Formal Analysis; Investigation; Methodology; Project administration; Supervision; Writing - original draft-; Writing-review & editing- João Victor Gomes Mota, Rodrigo Wenglarek Delorenzo, Guilherme Guidotti Botaro.

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Ethical Approval

Not applicable.

Informed Consent

Not applicable.

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Data Sharing Statement

No additional data are available.

Conflict of Interest

The authors declare no conflict of interest.

Similarity Check

It was applied by Ithenticate®.

Application of Artificial Intelligence (AI)

Not applicable.

Peer Review Process

It was performed.

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