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Exploring The Triad of Sleep, Pain and Mental Health in Adolescent Idiopathic Scoliosis: A Systematic Review

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ABSTRACT

Adolescent Idiopathic Scoliosis is a prevalent spinal deformity linked to back pain, psychosocial burden, and diminished quality of life. Recent evidence indicates that sleep disturbances represent a significant comorbidity in this population. This systematic review synthesises current findings on the prevalence of sleep disturbances, associated factors such as pain and mental health, and their impact on quality of life among adolescents with idiopathic scoliosis. The review followed PRISMA 2020 guidelines. A systematic search of PubMed, Scopus, and Google Scholar identified studies was published from January 2020 to October 2025. Ten studies met the inclusion criteria, comprising six cross-sectional, two case-control, one pilot, and one qualitative study, with sample sizes ranging from 11 to 19,315 participants. The prevalence of poor sleep quality ranged from 64.8% to 75.5%. Back pain and depressive symptoms were consistently associated with sleep disturbances. Short sleep duration (less than 8 hours) emerged as a potential risk factor, while brace treatment was associated with poorer sleep outcomes. Evidence also suggested an increased risk of sleep-disordered breathing. Overall, sleep disturbances, pain, and psychological distress frequently co-occur and are associated with reduced quality of life. However, these conclusions should be interpreted with caution, as no formal quality assessment of the included studies was performed.

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INTRODUCTION

Adolescent Idiopathic Scoliosis (AIS) is defined as a complex three-dimensional structural deformity of the spine, characterised by lateral curvature in the coronal plane (defined as a Cobb angle greater than 10°) and accompanied by vertebral rotation. This deformity appears during puberty, usually between the ages of 10 and skeletal maturity, without any specific identifiable aetiology (Cheng et al., 2015). AIS is the most common spinal disorder in adolescents, affecting approximately 1-3% of the global population in this age group. This condition shows a strong predilection for females, who have a significantly higher risk of curve progression compared to males, often requiring more intensive clinical intervention (Konieczny et al., 2013; Otomo et al., 2021).

The clinical impact of AIS extends far beyond visible cosmetic deformity. Patients often experience significant comorbidities that collectively contribute to a substantial decline in health-related quality of life (QOL) (Sun et al., 2024). Among various complaints, chronic back pain is consistently identified as the most frequently reported and most bothersome symptom (Wong et al., 2019). Physical and psychological complaints are highly prevalent, with qualitative studies finding that 'back pain' and poor 'sleep quality' are central themes in the lived experience of adolescents with AIS (Alamrani et al., 2023). This persistent pain burden, often exacerbated by muscle imbalances and biomechanical changes, forms the foundation for other secondary issues (Teles et al., 2019).

Effective management of AIS requires clinicians to look beyond Cobb angle radiographic measurements. The demands of long-term treatment, such as adherence to rigid orthopaedic bracing, combined with psychological concerns related to body image, create a significant psychosocial burden (Wang et al., 2021; Yakut et al., 2022). Assessing quality of life is often complicated by discrepancies in perception between patients and parents. Recent studies have found that parents tend to rate their children's self-image and mental health lower than the children themselves, and this perception gap correlates significantly with higher levels of psychological distress in adolescents (Zhang et al., 2025). A recent narrative review confirms that mental health disorders, including anxiety and depressive symptoms, have a higher prevalence in adolescents with AIS than in the general population, which is often exacerbated by treatment using braces (Mitsiaki et al., 2022). In addition, negative body image issues are often at the core of these psychosocial difficulties, which can trigger eating disorders and mood disorders (Gallant et al., 2018). Therefore, in recent years, research focus has shifted to understanding the complex interactions of the interrelated "triad" of comorbidities: chronic back pain, psychological dysfunction (such as depression and anxiety),

and sleep disorders (Yakut et al., 2022). The interaction of these three factors often creates a vicious cycle, where pain increases anxiety, and both contribute to sleep fragmentation.

Sleep is a fundamental biological process that is particularly crucial during adolescence, a period marked by rapid physical and neurological development. Adequate sleep is not only important for physical growth, but also essential for memory consolidation, emotional regulation, and systemic recovery of the body (Yakut et al., 2022). Substantial disturbances in sleep architecture, duration, or quality can have detrimental short-term consequences on academic functioning and mood, as well as long-term impacts on overall health. Given the importance of sleep, any disturbance in this process in AIS patients represents a significant clinical issue.

Emerging evidence from various clinical studies consistently shows that AIS patients are significantly more likely to suffer from sleep disorders than their healthy peers. These studies report a high prevalence of subjectively poor sleep quality (Yakut et al., 2022) and a greater risk for sleep-disordered breathing (SDB). The high prevalence of OSA risk detected in clinical screening suggests that this problem may be underdiagnosed in routine orthopaedic practice (Ugur et al., 2023).

The relationship between AIS and sleep disorders is highly complex and likely multifaceted, reflecting various pathophysiological pathways. Poor sleep quality may be a direct functional consequence of pain and positional discomfort due to the spinal deformity itself, which makes it difficult for patients to find or maintain a comfortable sleeping position (Yakut et al., 2022). Additionally, it may also be a significant iatrogenic side effect of treatment interventions, particularly the physical and psychological discomfort caused by the daily use of rigid orthopaedic braces (Salah et al., 2023). Severe thoracic deformities may also directly interfere with respiratory mechanics during sleep, although evidence for this requires further investigation.

Despite increasing attention to sleep disturbances in adolescents with idiopathic scoliosis, the existing literature remains fragmented. Most studies have examined sleep, pain, and psychological factors separately, with limited integration of these domains within a coherent biopsychosocial frame

work. Furthermore, the conceptual role of sleep in adolescent idiopathic scoliosis remains unclear, as it has been variably described as a symptom, a clinical outcome, or a potential risk factor. This lack of conceptual clarity limits the ability to interpret findings and translate evidence into clinical practice.

In this review, mental health is defined as encompassing depressive symptoms, anxiety, emotional distress, and body image concerns, which are commonly reported in adolescents with spinal deformities. Quality of life is conceptualised as a broader patient-reported outcome influenced by physical, psychological, and social domains, rather than as a primary exposure variable. Sleep is considered both as a clinical outcome and as a factor associated with adolescent idiopathic scoliosis and its related symptoms.

Therefore, this systematic review aims to: (1) determine the prevalence of sleep disturbances in adolescents with idiopathic scoliosis; (2) identify factors associated with sleep disturbances, including pain and mental health; and (3) synthesise how these domains are associated with quality of life and clinical outcomes. By addressing these objectives, this review seeks to provide a more integrated understanding of the relationship between sleep, pain, and psychological factors in adolescent idiopathic scoliosis.

METHODS

This systematic literature review was designed and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency and reproducibility (Page et al., 2021). An a priori protocol was developed to define the research questions, search strategy, eligibility criteria, and data synthesis methods. A comprehensive literature search was conducted in PubMed, Scopus, and Google Scholar to identify relevant studies published between 1 January 2020 and 1 October 2025. The time range was selected to capture the most recent evidence and ensure clinical relevance.

The search strategy incorporated three main domains: sleep, pain, and mental health. Boolean operators were used as follows: ("Adolescent Idiopathic Scoliosis" OR "AIS") AND ("sleep" OR "sleep quality" OR "insomnia" OR "sleep disordered breathing" OR "obstructive sleep apnoea") AND ("pain" OR "back pain") AND ("depression" OR "anxiety" OR "mental health"). Manual searches were also performed on the reference lists of included studies. All identified records were imported into a reference management tool, and duplicates were removed. Title and abstract screening were conducted independently by two reviewers, followed by full-text screening of eligible articles. Discrepancies between reviewers were resolved through discussion until consensus was reached.

Studies were included based on predefined Participants, Exposure, Comparison, Outcomes, and Study Design criteria. The inclusion criteria were: adolescents aged 10–19 years with a confirmed diagnosis of adolescent idiopathic scoliosis; studies evaluating sleep-related outcomes (including sleep quality, sleep duration, daytime sleepiness, or sleep-disordered breathing); and observational, pilot, or qualitative study designs. Studies were excluded if they involved non-idiopathic scoliosis, non-adolescent populations, case reports with fewer than 10 participants, review articles, or publications not available in English or Indonesian.

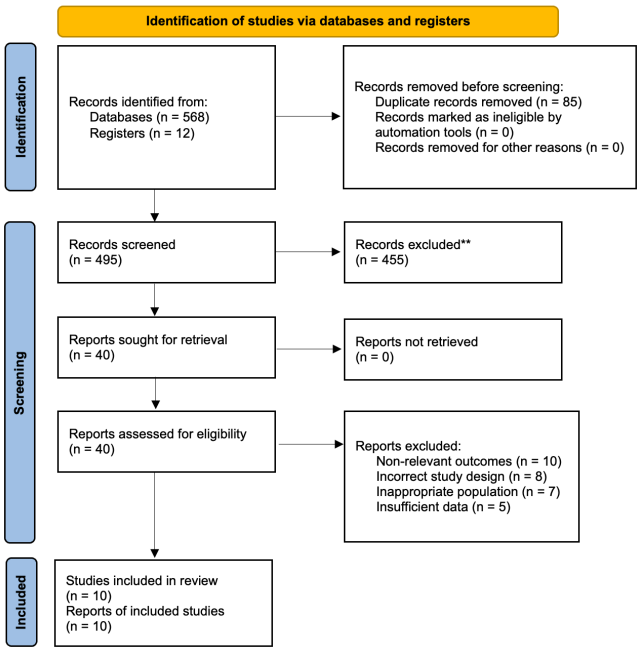


Figure 1. PRISMA Method Flowchart.

Sleep-related outcomes were broadly defined to include subjective sleep quality, sleep duration, daytime sleepiness, and sleep-disordered breathing. This approach was adopted to capture the multidimensional nature of sleep and its clinical relevance in adolescents with scoliosis. Mental health variables were defined as including depression, anxiety, emotional distress, and body image concerns. Quality of life was treated as a broader outcome influenced by these domains rather than as a primary variable.

Data extraction was performed using a standardised form, including study characteristics (author, year, country, design), sample characteristics (sample size, age range), measurement instruments, and key findings related to sleep, pain, and psychological variables. A narrative synthesis approach was used due to heterogeneity in study designs, outcome measures, and populations. Quantitative findings were summarised descriptively, while qualitative findings were integrated to provide contextual insight into patient experiences. A formal risk-of-bias or quality assessment of included studies was not conducted. This represents a limitation of the review and should be considered when interpreting the findings. Literature selection in this study used PRISMA. The flowchart based on the PRISMA method can be seen in Figure 1.

RESULTS OF STUDY

A total of 580 records were identified through database searching and registers. After removal of 85 duplicate records, 495 records remained for title and abstract screening. Of these, 40 full-text articles were assessed for eligibility, and 10 studies met the inclusion criteria. The main reasons for exclusion were non-relevant outcomes (n = 10), incorrect study design (n = 8), inappropriate population (n = 7), and insufficient data for extraction (n = 5).

The 10 included studies, published between 2022 and 2025, comprised six cross-sectional studies, two case-control studies, one pilot study, and one qualitative study, conducted across multiple countries including China, Tunisia, Turkey, Romania, and the United Kingdom. Sample sizes varied greatly, ranging from focused clinical cohorts (n=11 and n=15) to very large school-based population screenings (n=19,315). The most commonly used measures for sleep quality were the Pittsburgh Sleep Quality Index (PSQI) and the Paediatric Sleep Questionnaire (PSQ), or through specific domains within QOL questionnaires, as well as qualitative interviews. Pain and related disability were generally measured using specific pain questionnaires or identified as themes in qualitative studies. Quality of life is often measured with specific AIS instruments such as the Scoliosis Research Society 22 (SRS-22) or the Quality of Life Profile for Spine Deformities (QLPSD), as well as generic instruments such as the SF-12.

Table 1 presents a detailed summary of the 10 studies analysed. This table outlines the first author and year of publication, study design, sample size and type, primary measurement tools used, and key findings most relevant to sleep quality, pain, and related risk factors. Findings were synthesised according to outcome domains to enhance clarity and allow comparison across studies.

Sleep Quality

Several studies consistently reported a high prevalence of poor sleep quality among adolescents with adolescent idiopathic scoliosis. Yakut et al. (2022) found that 64.8% of patients had poor sleep quality based on Pittsburgh Sleep Quality Index scores. Qualitative findings also indicated that sleep disturbances are commonly experienced and are often related to physical discomfort, spinal deformity, and difficulty maintaining a comfortable sleeping position (Alamrani et al., 2023).

Sleep Duration and Lifestyle Factors

Evidence suggests that insufficient sleep duration (less than 8 hours per night) may be associated with adolescent idiopathic scoliosis. A large cross-sectional study involving 19,315 participants identified short sleep duration as a significant risk factor (Peng et al., 2025). In addition, lifestyle-related factors such as prolonged screen time and reduced physical activity were associated with increased risk of scoliosis and poorer sleep-related outcomes (Dou et al., 2023; Wang et al., 2025; Zhu et al., 2023).

Sleep-Disordered Breathing

Sleep-disordered breathing emerged as an important clinical consideration. Ugur et al. (2023) reported that approximately 32.9% of newly diagnosed adolescents had a high risk of obstructive sleep apnoea based on Paediatric Sleep Questionnaire scores. These findings suggest that respiratory-related sleep disturbances may be under-recognised in routine clinical assessment of adolescent idiopathic scoliosis.

Sleep and Pain

A consistent association between back pain and poor sleep quality was observed across multiple studies. Patients with poorer sleep quality tended to report higher pain intensity and greater functional impairment (Yakut et al., 2022). Qualitative evidence further supported that persistent back pain contributes to sleep disruption and discomfort during rest (Alamrani et al., 2023). Additionally, improvements in functional status and reductions in daytime sleepiness were observed following physiotherapy interventions, suggesting a potential link between pain management and sleep outcomes (Piele et al., 2023).

Sleep and Mental Health

Psychological factors, including depressive symptoms, anxiety, emotional distress, and body image concerns, were frequently associated with sleep disturbances. Higher levels of depression were linked to increased daytime sleepiness and poorer sleep profiles (Yakut et al., 2022). Qualitative findings highlighted that emotional distress and dissatisfaction with body image contributed to sleep difficulties and overall psychological burden (Alamrani et al., 2023).

Impact on Quality of Life

Several studies indicated that sleep disturbances, pain, and psychological distress were associated with reduced quality of life. Adolescents with adolescent idiopathic scoliosis consistently reported lower scores in domains related to pain, function, and mental well-being compared to healthy controls (Torén & Diarbakerli, 2022). Furthermore, adherence to recommended sleep and lifestyle behaviours was associated with improved mental components of quality of life (Sun et al., 2024).

Treatment-Related Factors

Evidence regarding treatment effects suggested that brace use may negatively impact sleep quality. Patients undergoing brace treatment reported worse scores in sleep-related domains, particularly in relation to sleep disturbance and discomfort (Salah et al., 2023). However, some studies also indicated that brace treatment may reduce pain levels, suggesting a complex interaction between treatment, pain, and sleep outcomes (Torén & Diarbakerli, 2022).

Table 1. Summary of 10 Analysed Studies

Author (Year)	Title	Study Design	Sample	Primary Measurement Tool	Key Findings Related to Sleep Quality
Yakut et al. (2022)	An investigation of sleep profiles in individuals with idiopathic scoliosis.	Cross-sectional	91 AIS	PSQI, ESS, SF-McGill, Beck Depression Scale	64.8% of AIS patients had poor sleep quality (PSQI > 5). Poor sleep was strongly correlated with pain and depression scores, but not with Cobb angle.
Ugur et al. (2023)	Paediatric Sleep Questionnaire for Sleep Apnoea in Newly Diagnosed AIS Patients.	Cross-sectional	299 patients (73 AIS)	PSQ, *Cobb* angle	33.4% of all patients at the scoliosis clinic had a high risk of OSA (PSQ > 0.33). 32.9% of newly diagnosed AIS patients had positive PSQ results.
Dou et al. (2023)	Academic-related factors and daily lifestyle habits associated with AIS: a case-control study.	Case-control	491 AIS, 1346 Controls	Questionnaire (Posture, Lifestyle)	AIS risk factors: poor reading/writing posture, heavy school bags, *screen time* > 2 hours, no milk consumption. (Sleep was not measured directly, but lifestyle was related).
Peng et al. (2025)	Positive rate and influencing factors of AIS among school children.	Cross-sectional (Screening)	19,315 students	Questionnaire (Risk Factors)	Risk factors for AIS: female, older age, low BMI, and insufficient sleep duration (< 8 hours/day).
Sun et al. (2024)	Association between meeting 24-hour movement behaviour guidelines and QOL in AIS.	Cross-sectional	1073 AIS	24-HMB (including sleep), SF-12 (QOL)	Only 1.9% met all three guidelines (physical activity, *screen time*, sleep). Meeting the sleep and *screen time* guidelines was strongly correlated with better mental QOL.
Salah et al. (2023)	Quality of life among adolescents with idiopathic scoliosis in Tunisia.	Cross-sectional	48 AIS (24 *brace*, 24 rehabilitation)	QLPSD, SRS-22, EVA-QOL	Patients wearing *braces* had significantly poorer QOL. The "Sleep Disturbance" domain on the QLPSD was significantly worse in the *brace* group.
Wang et al. (2025)	Behavioural effects of academic pressure on the risk of AIS: a case-control study.	Case-control	547 AIS, 2735 Controls	Questionnaires (Academic Pressure, Lifestyle)	Shorter sleep duration tends to increase the risk of AIS. Students with *screen time* exceeding 3 hours per day have a 2.08 times higher risk of scoliosis (OR = 2.08; 95% CI 1.06–4.09; p = 0.033), while outdoor activities for ≥ 3 hours per day reduce the risk by up to 65%.
Piele et al. (2023)	Relevance of Surface Electromyography Assessment and Sleep Impairment in Scoliosis: A Pilot Study	Pilot Study	15 children (AIS)	SEMG, Epworth (ESS-CHAD), Baecke, SAQ	Therapeutic intervention (Schroth & GPR) improved functional status. There was a significant difference (decrease) in Epworth scores (sleepiness) after therapy (p=0.002).
Alamrani et al. (2023)	Content validity of the Scoliosis Research Society questionnaire (SRS-22r): A qualitative concept elicitation study.	Qualitative Study	11 adolescents (AIS)	Semi-structured interviews (Thematic Analysis of HRQOL)	Sleep quality in AIS tends to decline due to persistent back pain, body asymmetry, and difficulty finding a comfortable sleeping position. Anxiety, stress, and concerns about physical condition and body appearance exacerbate sleep disturbances.
Torén & Diarbakerli (2022)	Health-related quality of life in adolescents with idiopathic scoliosis.	Cross-sectional	307 AIS, 80 Controls	EQ-5D, SRS-22r	Adolescents with idiopathic scoliosis have a lower quality of life compared to healthy adolescents, particularly in terms of function, pain, and mental health. This condition indicates impaired sleep quality due to physical discomfort, pain, and psychological stress associated with scoliosis.

DISCUSSION

This systematic review synthesised evidence from 10 recent studies and indicates that sleep disturbances are common in adolescents with adolescent idiopathic scoliosis and represent a clinically relevant concern rather than a secondary complaint. Across studies, poor sleep quality was consistently associated with pain and psychological factors (Alamrani et al., 2023; Yakut et al., 2022). However, as most included studies were observational, these findings should be interpreted as associative rather than causal.

The available evidence suggests that sleep disturbances, back pain, and psychological distress tend to co-occur and may influence one another within a biopsychosocial framework, rather than forming a definitively established causal cycle (Torén & Diarbakerli, 2022; Yakut et al., 2022). This interaction may be explained by shared neurobiological mechanisms, including central sensitisation and dysregulation of sleep architecture. Experimental evidence demonstrates that sleep deprivation can increase pain sensitivity and impair endogenous pain inhibition, while persistent pain contributes to sleep fragmentation and reduced sleep efficiency (Finan et al., 2013). In addition, sleep disruption may alter inflammatory pathways, including increased production of pro-inflammatory cytokines, which can further sensitise nociceptive pathways and amplify pain perception (Irwin, 2015).These bidirectional effects suggest that sleep and pain are closely interlinked through overlapping physiological pathways. Chronic pain may lead to increased nocturnal arousal and fragmented sleep, while sleep deprivation may reduce pain thresholds and exacerbate emotional reactivity, thereby contributing to psychological distress.These findings are consistent with the biopsychosocial model, which emphasises that health outcomes are shaped by the dynamic interaction between biological, psychological, and social factors rather than by structural pathology alone (Roberts, 2023).

Disease-Related Mechanisms

Back pain emerged as the most consistent factor associated with poor sleep quality. This relationship may be mediated by both mechanical and neurophysiological mechanisms. Biomechanical asymmetry and muscle imbalance in adolescent idiopathic scoliosis can lead to positional discomfort during sleep, while altered pain modulation pathways may increase sensitivity to nociceptive stimuli (Teles et al., 2019; Yakut et al., 2022). Qualitative findings further support this, with patients reporting difficulty maintaining comfortable sleeping positions (Alamrani et al., 2023). However, the lack of consistent association between curve severity and sleep outcomes suggests that subjective pain experience may be more relevant than structural deformity alone.

Psychosocial Mechanisms

Psychological factors, including depression, anxiety, and emotional distress, were consistently associated with sleep disturbances (Alamrani et al., 2023; Yakut et al., 2022). Notably, body image concerns appear to represent a key mediating factor. Adolescents with visible spinal deformity may experience negative self-perception and social anxiety, which can increase cognitive arousal at night and interfere with sleep initiation and maintenance. This highlights the importance of considering body image not only as a psychosocial outcome but also as a potential contributor to sleep disruption. This relationship is supported by broader literature indicating that sleep disturbances are strongly associated with mental health disorders, particularly depression and anxiety. Insomnia has been identified as both a symptom and a predictor of psychiatric conditions, potentially mediated by cognitive hyperarousal and altered stress response systems (Honaker & Meltzer, 2016; Paterson et al., 2013). In adolescents, these effects may be further intensified by developmental changes in circadian rhythm and emotional regulation (Kim et al., 2011; Liang et al., 2021).

Lifestyle and Behavioural Context

Lifestyle behaviours further contextualise these relationships. Insufficient sleep duration, excessive screen time, and low physical activity have been identified as modifiable factors associated with both adolescent idiopathic scoliosis and sleep disturbances (Dou et al., 2023; Peng et al., 2025; Wang et al., 2025; Zhu et al., 2023). From a behavioural perspective, increased screen exposure may delay circadian rhythms and reduce sleep duration, while reduced physical activity may impair both sleep quality and musculoskeletal health. In particular, screen use before bedtime may suppress melatonin secretion and delay sleep onset, thereby disrupting normal sleep patterns (Cain & Gradisar, 2010). These behavioural patterns may not only contribute to sleep disturbances but also indirectly influence the progression and symptom burden of adolescent idiopathic scoliosis, highlighting important targets for preventive and lifestyle-based interventions.

Sleep-Disordered Breathing and Physiological Considerations

An important but less frequently discussed finding is the elevated risk of sleep-disordered breathing in this population (Ugur et al., 2023). Thoracic deformity may alter respiratory mechanics, potentially contributing to nocturnal hypoxia and sleep fragmentation. This suggests that, in some patients, sleep disturbances may have a physiological basis that extends beyond pain and psychological factors.

Treatment-Related Trade-Offs

The impact of treatment, particularly brace use, appears to be complex and multifactorial. While bracing may reduce curve progression and, in some cases, pain, it may simultaneously introduce physical discomfort and restrict movement during sleep (Salah et al., 2023). This highlights a potential trade-off between structural correction and patient-reported outcomes, underscoring the need for patient-centred treatment planning.

Integration with Quality of Life

Sleep disturbances, pain, and psychological distress were consistently associated with reduced quality of life (Sun et al., 2024; Torén & Diarbakerli, 2022). Importantly, quality of life should be conceptualised as an outcome influenced by multiple interacting domains rather than as an independent variable. This reinforces the value of a multidimensional assessment approach in both research and clinical practice.

Clinical Implications

These findings support a shift from a purely structural model of adolescent idiopathic scoliosis management

towards a biopsychosocial approach. Routine assessment of sleep quality, pain, and psychological well-being may help identify patients at higher risk of poor outcomes. Interventions targeting sleep hygiene, pain management, and psychological support may provide additional benefits beyond traditional orthopaedic treatment. Evidence from chronic pain research suggests that improving sleep quality may lead to downstream benefits in pain reduction and psychological functioning, supporting the inclusion of sleep-focused interventions within multidisciplinary management strategies (Whale & Gooberman-Hill, 2022).

Limitations

This review has several limitations. The predominance of observational studies limits causal inference, and heterogeneity in outcome measures complicates comparison across studies. The reliance on self-reported instruments introduces potential reporting bias. Additionally, no formal risk-of-bias assessment was conducted, which limits evaluation of evidence quality. The absence of meta-analysis further restricts quantitative interpretation.

Future Directions

Future research should prioritise longitudinal designs to clarify temporal relationships and potential causal pathways. Intervention studies targeting sleep, pain, and psychological factors are needed to determine whether modifying these variables can improve clinical outcomes. Greater emphasis on body image and psychosocial interventions may also provide valuable insights into improving quality of life in adolescents with adolescent idiopathic scoliosis.

CONCLUSIONS AND RECOMMENDATION

Conclusion

This systematic review indicates that sleep disturbances are common in adolescents with adolescent idiopathic scoliosis and represent a clinically relevant concern. The available evidence suggests that poor sleep quality is consistently associated with back pain and psychological factors, including depressive symptoms and emotional distress. These domains tend to co-occur and are associated with reduced quality of life. However, the current evidence is predominantly observational, and therefore causal relationships between sleep, pain, and psychological factors cannot be established. Sleep should be considered both as a clinical outcome and as a factor associated with adolescent idiopathic scoliosis within a broader biopsychosocial framework. Overall, these findings support the importance of incorporating sleep assessment into routine clinical evaluation, alongside physical and psychological assessment, to better understand patient experiences and improve holistic care.

Recommendations

Future research should prioritise longitudinal and prospective study designs to clarify the temporal and potential causal relationships between sleep disturbances, pain, and psychological factors in adolescents with adolescent idiopathic scoliosis. Intervention-based studies, including randomised controlled trials, are needed to evaluate the effectiveness of sleep-focused interventions, pain management strategies, and psychosocial support in improving patient outcomes and quality of life. Further research should also explore the role of body image and psychosocial factors as potential mediators linking physical deformity, emotional distress, and sleep disturbances. In clinical practice, a multidisciplinary and biopsychosocial approach is recommended, integrating orthopaedic management with sleep assessment, pain management, and psychological support to optimise overall patient care.

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Conflicts of interest

The authors declare that they have no competing interests.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

This study is based entirely on previously published literature and did not involve collecting primary data. All data supporting the findings of this review are available within the cited articles. Additional supporting documentation, such as search strategies or data extraction matrices, may be requested from the corresponding author.

Artificial Intelligence-Assisted Technology

AI tools, including ChatGPT (OpenAI), DeepL, and Grammarly, were used exclusively to support language polishing, grammar refinement, and clarity improvement. The authors affirm that all scientific interpretation, conceptual development, methodological procedures, screening decisions, and synthesis processes were conducted entirely by the authors. No AI tools were used to generate, analyze, or manipulate scientific data.

Authors' contributions:

First Author (M.A. Maharani): M.A. Maharani led the conceptualization of the study, designed the review protocol, conducted the systematic search process, performed study screening and data extraction, and drafted the manuscript. M.A. Maharani was also responsible for coordinating the review process and ensuring the overall quality and integrity of the study.

Second Author (A.D. Pratama): A.D. Pratama contributed to methodological supervision, critical appraisal of the

included studies, validation of the data synthesis, and refinement of the final manuscript. A.D. Pratama also provided substantial revisions and intellectual input to improve the clarity and scientific rigor of the article.

All authors have read and approved the final version of this manuscript and agree to submit this article for publication.

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