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# The Impact of Competitive Asymmetric Sports on the Development of Idiopathic Scoliosis in Young Athletes: A Literature Review

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# Abstract

**Background:** Adolescent Idiopathic Scoliosis (AIS) is a three-dimensional spinal deformity with a multifactorial and not yet fully clarified etiology, affecting 2–3% of adolescents. The influence of sports—as an environmental factor—on the risk and progression of AIS remains debated, particularly in the case of asymmetric disciplines characterized by repetitive unilateral movements.

**Objective:** This systematic review aimed to evaluate the impact of competitive asymmetric sports on the development and progression of AIS in young athletes, with specific consideration of relevant risk factors.

**Methods:** A systematic search of PubMed and PubMed Central databases (Nov 2002–Jun 2025) was conducted between June 10–15, 2025. Eligible publications included original studies, reviews, and meta-analyses involving participants ≤18 years old. Data extracted addressed AIS prevalence, risk factors (training intensity, age of onset, gender, hypermobility), and clinical outcomes (Cobb angle progression, bracing, surgical treatment).

**Results:** The reviewed literature indicates that asymmetric sports can significantly affect AIS prevalence. The highest rates (up to 30–35%) were reported among gymnasts and ballet dancers. Young volleyball and basketball players also demonstrated a higher prevalence compared to the general population (2–3%). Racket sports such as tennis were associated with marked

muscle asymmetry and increased spinal torsion. Conversely, regular recreational physical activity exhibited a protective effect: adolescents not engaged in sports showed an increased risk of curve progression (RR = 1.57; p = 0.004) and of requiring bracing (RR = 1.85; p = 0.007).

**Conclusions:** Early and intensive participation in asymmetric sports may elevate the risk of AIS progression, whereas recreational activity has compensatory and protective properties. Clinical practice should emphasize posture monitoring, implementation of individualized compensatory exercise programs, and appropriate modulation of training loads in young athletes.

**Keywords:** adolescent idiopathic scoliosis; asymmetric sports; adolescents; scoliosis progression; ballet; gymnastics; volleyball; basketball; tennis; football

# 1. Introduction

Adolescent Idiopathic Scoliosis (AIS) is a three-dimensional spinal deformity with a not fully elucidated etiology. Affecting approximately 2–3% of adolescents, it may progress to the extent that conservative or surgical treatment becomes necessary. As the popularity of competitive sports among children and adolescents continues to grow, so too does interest in the potential influence of sports participation on the development and progression of AIS [1].

Particular attention has been directed toward asymmetric sports characterized by repetitive, unilateral movement patterns-such as gymnastics, ballet, tennis, other racket sports, football, volleyball, and basketball. Many authors have suggested that these disciplines may reinforce trunk and limb asymmetries, thereby promoting scoliosis progression. Conversely, several studies indicate that general sports participation can have a protective effect by reducing the likelihood of curve progression and the need for bracing [2].

Existing findings remain inconsistent: some studies report higher AIS rates among athletes, while others do not observe significant differences when compared with non-athletes. Relevant modifiers include gender, training intensity, age at sport initiation, and individual predispositions (hypermobility, delayed maturation, genetic factors) [3, 4].

The objective of this review is to synthesize current evidence concerning the impact of asymmetric sports on AIS development and progression in young athletes, taking into account

discipline-specific characteristics, training load, age, and both early and long-term consequences.

# 2. Objective

The purpose of this systematic review was to assess the impact of competitive participation in asymmetric sports on the development and progression of adolescent idiopathic scoliosis.

Specific objectives included:

- determining AIS prevalence across selected asymmetric disciplines,
- analyzing the relationship between training intensity and curve progression risk,
- identifying risk factors contributing to AIS in asymmetric sports,
- presenting early adverse effects (muscle imbalance, pain, postural deviations) and long-term consequences (surgical treatment, persistent deformity).

# 3. Materials and Methods

## 3.1 Search Strategy

A literature search was conducted in PubMed and PubMed Central (Nov 2002–Jun 2025) between June 10–15, 2025. The search strategy combined the following keywords and Boolean operators: ("adolescent idiopathic scoliosis" OR AIS) AND ("asymmetric sports" OR "unilateral sports" OR "lateral dominance") AND (prevalence OR incidence OR risk OR progression), in addition to discipline-specific terms (gymnastics, ballet, volleyball, basketball, tennis, football, soccer). Peer-reviewed original studies, reviews, and meta-analyses published in English and available in full text were included.

Relevant literature was sourced from journals including the *European Journal of Physical and Rehabilitation Medicine*, *BMJ Sports & Exercise Medicine*, *Journal of Bone and Joint Surgery*, *PeerJ*, *Medicina*, *Life*, *Healthcare*, and *Sports*, among others indexed in PubMed and PubMed Central.

## 3.2 Inclusion Criteria

- population: children and adolescents (≤18 years),
- diagnosis: AIS or risk thereof,
- exposure: regular participation in an asymmetric sport (gymnastics, ballet, tennis, football, volleyball, basketball),
- outcome: AIS prevalence, Cobb angle progression, need for bracing or surgical intervention.

## 3.3 Exclusion Criteria

- congenital, neuromuscular, or adult-onset scoliosis,
- populations >18 years,

- descriptive studies lacking empirical data.

## 3.4 Data Selection and Analysis

The selection process identified 427 records. After removal of duplicates (n = 58) and title/abstract screening, 87 articles underwent full-text review. Ultimately, 24 studies met the inclusion criteria.

Data extraction encompassed epidemiological parameters (AIS prevalence), biomechanical findings (muscle asymmetry, posture), clinical progression data (Cobb angle, treatment), and psychosocial outcomes (pain, quality of life). Results are presented as a narrative synthesis.

# 4. Literature Review

## 4.1 Types of Asymmetric Disciplines

### Football

Football is widely practiced among youth and inherently promotes functional asymmetries. Research demonstrates that young football players often exhibit notable differences in hip and knee range of motion between dominant and non-dominant limbs, particularly in abduction and adduction [10]. These asymmetries mirror the unilateral loading inherent to football such as repetitive kicking or dynamic turns executed primarily with the dominant leg [11].

Such load-induced asymmetries may influence pelvic alignment and trunk posture, especially during rapid growth, increasing the risk of compensatory spinal curvature. Resulting musculoskeletal imbalances are considered potential contributors to AIS progression [10]. Over time, insufficiently corrected asymmetries may increase the likelihood of spinal deformities and the need for conservative treatment [12].

### Volleyball

Volleyball involves repetitive unilateral overhead movements (serves, spikes, and blocks) leading to dominance of the upper limb on one side. Biomechanical analyses show that these repetitive actions generate strength and functional imbalances in the shoulder girdle and trunk, which may contribute to altered spinal curvature [13, 14].

A retrospective study of 116 adolescent volleyball players (mean training duration: 4.2 years) found significantly higher rates of trunk asymmetry and scoliosis compared with a large control group (n = 46,428) [15]. Key findings included:

- 42% positive Adams forward bend test versus controls,
- 17% with Angle of Trunk Rotation >5°,
- 5.2% meeting radiographic scoliosis criteria, compared with 1% in controls.

Additionally, curve direction frequently correlated with the player's dominant hand. These findings support the relationship between unilateral volleyball movements and increased postural asymmetry and scoliosis risk [15].

## Basketball

Although basketball engages the entire body, many technical movements (shooting, dribbling, pivoting) are performed predominantly on the dominant side. Studies report that musculoskeletal disorders, including altered spinal alignment, may affect up to 30% of young players [16]. Strength and neuromuscular asymmetries between sides are commonly observed and may influence spinal posture. Without adequate compensatory training, long-term basketball participation may contribute to AIS progression during the growth period [17].

## Tennis and Racket Sports

Tennis represents a prototypical unilateral sport. Serving and groundstrokes executed with the dominant upper limb produce repetitive, high-load forces, resulting in muscle hypertrophy on one side, shoulder girdle asymmetry, and altered spinal mechanics, including trunk rotation [18]. Similar patterns are observed in badminton and squash, where unilateral limb loading and rapid directional changes further accentuate asymmetry [19].

Clinically, athletes in racket sports more frequently report back pain and motion limitations, and without corrective strategies, may be at increased risk for scoliosis progression [20].

## Gymnastics

Gymnastics—both artistic and rhythmic—is among the most extensively studied disciplines in relation to AIS. Numerous publications report that the prevalence of scoliosis is significantly higher among gymnasts compared with the general population. At the same time, authors highlight that this is not solely the result of training. High joint hypermobility, common among gymnasts, predisposes to AIS and may influence the selection of this sport [21].

Long-term gymnastics training during the growing years, particularly the repetitive acrobatic and balance elements, exposes young athletes to recurrent asymmetric spinal loading. The risk of curve progression is greatest in girls aged 9–13 years, especially those with low skeletal maturity (Risser 0–1) and rapid growth exceeding 2 cm per year [23].

### Ballet

Ballet is the discipline with the highest documented prevalence of AIS. A meta-analysis by Mousavi et al. (2022) reported rates reaching up to 35%, several times higher than in the general adolescent population [3]. Contributing factors include extreme ranges of motion, turnout positions, repetitive pirouettes, and asymmetric pelvic mechanics, all of which may exacerbate an underlying predisposition to spinal deformities [24].

Key risk factors in ballet dancers include:

- very early training initiation (mean age 5.8 years),
- high weekly training volume (approx. 22 h/week),

- low BMI (≈15.7% classified as undernourished),
- delayed menarche (mean 13.9 years),
- differences in bone mineral density.

Each of these factors has been identified as potentially increasing the likelihood of AIS development or progression [8].

## 4.2 Training Intensity and Frequency

A retrospective study involving 511 adolescents with AIS (11–25° Cobb, Risser 0–2) demonstrated that absence of sports participation was associated with a higher risk of curve progression ≥5° (RR = 1.57; p = 0.004) and a higher likelihood of reaching the bracing threshold (≥25° Cobb) (RR = 1.85; p = 0.007) [2].

Logistic regression further confirmed that more frequent sports participation correlated with significantly lower odds of AIS progression (p = 0.0004) and reduced need for bracing (p = 0.004). However, these findings refer to general physical activity rather than specific types of sports.

In contrast, competitive asymmetric sports may impose unilateral mechanical stress that can intensify muscle imbalances and contribute to curve progression in predisposed individuals [17].

## 4.3 Age and Gender

AIS is substantially more common in girls than boys, with an approximate ratio of 3:1, and the highest risk of progression occurs during skeletal immaturity (Risser 0–2) [3]. Rapid growth increases susceptibility to asymmetric forces, which can influence vertebral growth plates and contribute to deformity stabilization [17].

Early participation in asymmetric sports—such as gymnastics, ballet, or tennis—appears particularly impactful among girls with hypermobility or delayed maturation. The combination of biological predisposition and intensive training may be decisive in the onset and progression of spinal curvature [23].

## 4.4 Early and Long-Term Consequences

**Early consequences:**

- asymmetry of trunk and limb musculature,
- postural deviations (hyperlordosis, hyperkyphosis),
- back pain resulting from unilateral overloading.

**Long-term consequences:**

- fixed deformities requiring surgical intervention,
- reduced spinal mobility after the end of sports participation,
- increased likelihood of chronic back pain in adulthood.

Persistent asymmetric loading without appropriate compensatory training may ultimately decrease the adaptability of the musculoskeletal system and negatively affect quality of life [5, 16].

# 5. Summary

The reviewed evidence indicates that participation in asymmetric sports may increase the risk of AIS development and progression—particularly among girls who begin intensive training at a young age. The highest prevalence of scoliosis is observed in ballet and gymnastics, but elevated risk is also reported in tennis, volleyball, basketball, and football.

In contrast, regular recreational physical activity has a distinctly protective effect, reducing both curvature progression and the likelihood of requiring bracing.

**Practical recommendations:**

- careful regulation of training load in youth participating in asymmetric sports,
- routine postural assessments and implementation of targeted compensatory exercise programs,
- further prospective research considering sport type, training intensity, and age of initiation,
- promoting frequent recreational activity as a protective factor,
- acknowledging that intensive asymmetric training may act as a risk factor during periods of rapid skeletal growth.

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In preparing this work, the authors used ChatGPT for the purpose of checking language accuracy. After using this tool/service, the authors have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

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