Review Article

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Long-term Sustainability of Posture Correction during Adolescent Growth: A Narrative Review

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ABSTRACT

Adolescence is marked by fast somatic growth and neuromuscular development, which have a big impact on spinal biomechanics and postural alignment. Skeletal elongation may momentarily surpass the muscles and connective tissues ability to adapt during the adolescent growth spurt, especially around Peak Height Velocity (PHV), resulting in postural abnormalities as Forward Head Posture (FHP), rounded shoulders, and thoracic kyphosis. These changes have been linked to a rise in the mechanical strain on spinal structures and the emergence of musculoskeletal pain in adolescents. The aim of this narrative review is to provide an overview of posture correction interventions and to interpret the long-term sustainability of those interventions. Corrective exercises, postural education, and ergonomic interventions are common rehabilitation techniques used to treat postural disorders. While many studies report improvement in posture, evidence regarding long-term maintenance of those corrections remains limited. Understanding impact of adolescent growth spurt and PHV is essential and hence further longitudinal research is needed to develop effective long-term sustainability of posture corrections.

Keywords: Adolescent growth spurt, Adolescent posture, Musculoskeletal pain, Peak height velocity

INTRODUCTION

Posture is defined as the alignment of body segments relative to each other and to the gravitational line during static and dynamic activities. Optimal posture enables efficient movement and minimises mechanical stress on joints, ligaments, and muscles [1]. In contrast, prolonged postural deviations can increase biomechanical loading on spinal structures and may contribute to musculoskeletal pain and functional impairment [2]. Adolescence is a period of rapid height growth, marked by the adolescent growth spurt, during which children mature physically, mentally, and emotionally in extremely brief amount of time [3]. During this phase, adolescents experience fast height gain, considerable alterations in body proportions, and neuromuscular coordination [4]. PHV is a crucial indicator of biological maturation, marking the greatest rate of height rise [5]. Rapid skeletal growth during adolescence may momentarily surpass the adaptive ability of muscles and connective tissues. This condition can cause muscle imbalance and changed biomechanical connections in the spine and adjacent structures. As a result, adolescents may be more sensitive to postural abnormalities during periods of rapid growth [6].

There is compelling evidence that the prevalence of pain rises with age during the adolescent stage, typically occurring slightly sooner in girls, maybe coinciding with puberty and that girls are more likely than boys to experience it [7]. The precise balance of the vertebral column is well known, and any alteration to one area will be offset by other areas. Large breasts appear to affect the lumbar and thoracic portions of the spinal column. Breast size appears to have a considerable impact on posture, notably the angles of lumbar lordosis and thoracic kyphosis [8]. Towards the end of adolescence, the prevalence of musculoskeletal pain approaches that of adults. An increased likelihood of chronic pain in adulthood is associated with persistent musculoskeletal discomfort in adolescents. School and school-related activities play a significant role in life and have a big influence on children's growth [9].The prevalence of bad posture among adolescents has increased due to modern lifestyle choices in addition to biological growth factors. Sustained neck flexion and altered spine alignment have been linked to prolonged sitting during courses of study excessive smartphone and digital device use, and decreased physical activity levels [10]. The developing musculoskeletal system may experience increased biomechanical stresses as a result of such behavioural adaptations.

Physiotherapy interventions are widely used to address postural abnormalities in adolescents. Corrective exercise programs focusing on strengthening postural muscles, stretching shortened structures, and improving neuromuscular control have been shown to improve spinal alignment and reduce musculoskeletal symptoms [11,12]. Postural education and ergonomic modifications are also important components of rehabilitation programs. Despite the effectiveness of these interventions in improving posture, the long-term sustainability of posture correction during adolescent growth remains a critical concern. Because adolescents continue to experience changes in skeletal structure and neuromuscular coordination, improvements achieved through rehabilitation may require ongoing monitoring and reinforcement. Therefore, understanding the relationship between growth-related changes, particularly around PHV, and the effectiveness of rehabilitation interventions is essential for developing strategies that promote sustainable posture correction.

This narrative review aims to examine the influence of adolescent growth on postural development and to evaluate available evidence regarding the long-term impact of rehabilitation interventions designed to correct postural deviations during this critical developmental period.

This narrative review aimed to synthesise literature on posture correction interventions and their long-term sustainability in adolescents, considering growth, lifestyle, and rehabilitation factors. A comprehensive search was conducted across PubMed, Scopus, and Web of Science for studies published between 2000 and 2026, using keywords and MeSH terms such as adolescent posture, posture correction, growth spurt, PHV, musculoskeletal pain, physiotherapy interventions, corrective exercise, ergonomics, and long-term outcomes, combined with Boolean operators. Relevant studies were identified through title and abstract screening, followed by full-text assessment based on predefined inclusion and exclusion criteria, with additional articles sourced from reference lists. Only English-language studies involving adolescents

aged 10-19 years and focusing on neck and upper back posture interventions like stretching, strengthening, corrective exercises, and posture education were included, while studies on adults, elderly populations, and surgical management of spinal deformities were excluded. Extracted data were synthesised to evaluate the effectiveness of postural correction strategies.

REVIEW OF LITERATURE

The present review provides an overview about posture correction and interprets long-term sustainability of those interventions as shown in [Table/Fig-1] [13-24]. The findings from the included studies provide information about effects of various interventions on outcomes of upper body posture in adolescent age group.

DISCUSSION

Based on the existing evidence, literature was categorised into two domains.

Adolescent Growth Spurt and Musculoskeletal Adaptations

Adolescent musculoskeletal growth and postural control are significantly shaped by rapid biological maturation. The teenage growth spurt, which is marked by a sharp rise in height and alterations in body proportions, is one of the most important events that occur during this time. The time that the rate of longitudinal growth reaches its greatest is known as the period of PHV, or PHV. Hormonal shifts, changes in neuromuscular coordination, and rapid skeletal development are all linked to this stage. The surrounding muscles, tendons, and ligaments may momentarily lag behind in adjusting to the increased skeletal dimensions because bones lengthen quickly during this stage. Adolescents are especially vulnerable to postural abnormalities and musculoskeletal discomfort during times of rapid growth because this imbalance can lead to decreased flexibility, changed muscle strength ratios, and diminished postural stability [4].

Spinal alignment and biomechanics may also be impacted by the fast skeletal elongation seen during the growth spurt. The neuromuscular system must constantly adjust to maintain balance and effective movement as long bones and vertebral bodies grow rapidly. Skeletal development and neuromuscular control, however, are not always synchronised. Adolescents obtaining PHV may temporarily lose their motor control and proprioception, which may result in compensatory movement patterns and postural changes, according to studies. These adjustments could show up as altered lumbar lordosis, increased thoracic kyphosis, or forward head position. Adolescent musculoskeletal pain may be exacerbated by these alterations, which could put more mechanical strain on the spine and associated soft-tissues [25].

Genetic and biological sex characteristics affect the timing and severity of PHV, which varies from person to person. Boys normally experience PHV between the ages of 13 and 14, although girls typically experience it earlier, usually between the ages of 11 and 12. The variations in postural development and musculoskeletal complaints between male and female adolescents may be partially explained by these maturation differences. Due to increased biomechanical stress on developing tissues, early or quick growth spurts may make a person more susceptible to musculoskeletal pain [26].

Another important aspect of the adolescent growth spurt is the alteration in body proportions, including increases in limb length and trunk dimensions. These changes shift the body's center of mass and require continuous adjustments in postural control mechanisms. During this transitional period, adolescents may exhibit decreased balance and increased variability in movement patterns as the neuromuscular system adapts to new biomechanical demands. Rapid growth may potentially impair coordination and raise the risk of musculoskeletal strain, according to research on growth-related motor development. This is especially true when adolescents participate in extended periods of inactivity or repetitive postures [27-29].

Sustainability of Posture Correction during Adolescent Growth

Although physiotherapy interventions such as corrective exercises, strengthening programs, and postural education have

Author and Year	Population	Intervention	Outcome measure	Findings
Bhandary V et al., (2025) [13]	13 to 15 years, both genders	Cervical and shoulder stretching and strengthening (4 days/week for 4 weeks)	Cranio-vertebral angle, shoulder protrusion, thoracic kyphosis	Reduced Forward Head Posture (FHP), protracted shoulders and Thoracic kyphosis.
Baek CY et al., (2025) [14]	14 to 17 years, both genders	Digital health corrective posture exercise, face to face exercise (3 days/week for 6 weeks)	Protracted head, trunk lean, trunk deviation, shoulder and pelvic height levels	Effective in improving head and shoulder posture.
Ruivo RM et al., (2016) [15]	15 to 17 years, both genders	Strengthening and stretching exercises (2/week for 16 weeks)	Sagittal head, cervical and shoulder angles	Posture improvement with increase in cervical and and shoulder angle.
Feng Q et al., (2017) [16]	12 to 15 years, both genders	Corrective functional exercise program (2/week for 8 weeks)	Thoracic kyphosis angle, lumbar lordosis angle, sacral angle, incline angle	Improved exaggerated thoracic kyphosis.
González-Gálvez N et al., (2020) [17]	12 to 17 years, both genders	Pilates exercise program (2/week for 9 Months)	Sagittal spinal curve	Decreased lumbar curvature, Increased thoracic curvature.
Elpeze G and Usgu G, (2022) [18]	10 to 18 years, both genders	Comprehensive corrective exercise program, thoracic exercise program (3/week for 12 weeks)	Kyphosis angle	Kyphosis angle was reduced.
Park YJ et al., (2022) [19]	10 to 19 years, both genders	Stretching and Schroth muscle exercise (3/week for 24 weeks)	Cobb's angle, forward head angle	Improved cobb's angle and forward head angle.
Gheitasi M et al., (2022) [20]	11 to 16 years, both genders	Corrective exercises, bracing protocol (3/week for 24 weeks)	Cobb's angle	Better outcome in Cobb's angle by combined intervention.
Shadi N et al., (2024) [21]	13 to 15 years, only females	Corrective exercises, alexander training, pilates exercises (3/week for 6 weeks)	Thoracic kyphosis angle, rounded shoulder angle, forward head angle	Improved forward head angle, rounded shoulder and thoracic kyphosis.
Esmaeili Z et al., (2021) [22]	14 to 16 years, only females	Functional Corrective Exercises (FCE), Core Stability Exercise (CSE), combined program (3/week for 6 weeks)	Forward head angle, kyphosis angle	Improved forward head and kyphosis angle.
Klobucká S et al., (2025) [23]	11 to 17 years, both genders	Coordination dynamics therapy (2/week for 10 weeks)	Spine mobility, muscle strength, postural stability	Improved spine mobility and postural stability.
Barzegari M and Majelan AS (2026) [24]	9 to 12 years, male only	postural education, corrective games (2 days/week for 8 weeks)	Kyphosis angle, Forward Head Posture (FHP), forward shoulder posture	Reduced kyphosis angle, Forward Head Posture (FHP), forward shoulder posture.

[Table/Fig-1]: Included studies and findings [13-24].

demonstrated effectiveness in improving spinal alignment and muscular balance, maintaining these improvements during the rapid growth phase can be challenging. As adolescents continue to grow, changes in skeletal dimensions and body proportions may alter previously established neuromuscular patterns. Consequently, posture correction achieved during one stage of growth may not be sustained if the intervention is discontinued or if the musculoskeletal system continues to change rapidly. Longitudinal studies indicate that without ongoing reinforcement and monitoring, adolescents may revert to previous faulty postural habits due to environmental influences such as prolonged sitting, digital device use, and reduced physical activity [9].

The FHP and related issues can be improved through corrective exercises and manual therapy. Kendall exercises focus on stretching tight muscles like neck extensors and pectorals while strengthening weak deep neck flexors and scapular retractors to correct posture and improve neck and shoulder function. Global Postural Reeducation (GPR) is a holistic technique that uses sustained stretching positions combined with controlled muscle activation and breathing to restore balance across the body's muscle chains. It works on the principle that the body is interconnected through fascia, allowing force transmission across different regions, which supports overall mobility and reduces pain. While both local and global approaches are effective, combining Kendall Exercises with GPR may provide better outcomes in improving posture, mobility, and functional ability in individuals with FHP [30].

The results of the systematic review by Sepehri S et al., indicate that the prescription of various therapeutic exercises is effective in improving postural alignment in individuals with Upper Crossed Syndrome (UCS). Specifically, exercise interventions contribute to significant improvements in FHP, rounded shoulders, and thoracic kyphosis angles. However, the effectiveness of these interventions appears to be comparatively lower in children than in adults. When interpreting these findings, certain limitations should be acknowledged. Notably, most of the included studies did not investigate the long-term effects of therapeutic exercise on UCS, making it difficult to determine the durability and sustainability of the reported improvements over time [31].

The findings of the study by Barzegari M and Majelan AS, demonstrated that both the posture education group and corrective gymnastics games groups showed significant improvements, including reductions in kyphosis angle, FHP, and forward shoulder posture, along with better daily postural habits in children. However, after a three-month follow-up period, no further significant changes were observed in these variables. This suggests that while such interventions are effective in the short-term, maintaining these improvements over time may be challenging. The lack of continued progress or retention could be attributed to reduced adherence to exercise programs, insufficient reinforcement of correct postural behaviours, or the absence of ongoing supervision. Therefore, long-term sustainability of postural correction may require continuous practice, behavioural reinforcement, and integration of postural awareness into daily activities [24].

Wearable devices show potential for producing short-term improvements in cervical and thoracic posture and may influence muscle activation patterns; however, the long-term durability of these effects, their true clinical significance, and their impact on symptoms and functional outcomes remain uncertain. Current evidence does not clearly establish whether these changes represent meaningful therapeutic benefits or are simply temporary, sensor-driven adjustments. Therefore, more rigorous research is needed, particularly high-quality randomised controlled trials with larger and more diverse populations, standardised outcome measures, and extended follow-up periods, to better evaluate the effectiveness, safety, and long-term value of wearable technologies in improving posture and musculoskeletal health [32].

For long-term sustainability, these programs emphasise the correction of body alignment, strengthening of supporting musculature, and improvement of shoulder stability, alongside the reinforcement of appropriate movement patterns. These components play a critical role in enhancing proprioceptive awareness and neuromuscular control of posture. Improved postural awareness facilitates the maintenance of correct alignment during functional activities. Consequently, such interventions not only yield immediate improvements but also contribute to the development of long-term behavioural adaptations, thereby supporting sustained spinal alignment, stability, and overall musculoskeletal health [24].

The long-term sustainability of posture correction is further complicated by the dynamic nature of adolescent growth. Rehabilitation programs that produce short-term improvements may not account for the continuous biomechanical adjustments required throughout the growth period. As a result, posture correction strategies must consider the timing of interventions relative to growth stages, particularly around PHV, when musculoskeletal changes are most pronounced. Continuous reassessment, progressive exercise programs, and integration of posture education into daily activities may therefore be necessary to maintain postural improvements during adolescence [12,33].

Overall, the adolescent growth spurt and the period surrounding PHV represent critical phases in musculoskeletal development during which postural deviations are more likely to occur. Rapid skeletal growth, temporary neuromuscular imbalance, and changes in body proportions can challenge the maintenance of optimal posture. Although rehabilitation interventions can effectively improve postural alignment, sustaining these improvements throughout the growth phase requires long-term adherence, monitoring, and adaptation of treatment strategies to accommodate ongoing developmental changes [33]. Understanding the relationship between growth patterns and postural control is therefore essential for designing interventions that promote sustainable posture correction during adolescence.

There is considerable heterogeneity among studies investigating posture correction exercises, with variations in exercise types, protocols, duration, frequency, and the inclusion of additional therapeutic interventions. The studies also report variability of outcome measures across the study. Moreover, the number of high-quality randomised controlled trials is limited, and many quasi-experimental studies lack proper control groups, increasing the risk of confounding bias. Most studies also involve small sample sizes and short intervention periods, with a notable absence of long-term follow-up assessments. As a result, it remains difficult to draw firm conclusions about the durability of improvements or the long-term sustainability of postural correction and motor learning achieved through these exercises.

Limitation(s)

Interaction between growth related changes during adolescence phase and posture correction strategies has not been extensively explored in the longitudinal research. There is limited evidence regarding improvement of posture during early phases of growth spurt and its sustainability as adolescence progresses towards PHV and beyond.

CONCLUSION(S)

Rehabilitation strategies including corrective exercises, postural education, and ergonomic modifications can improve postural alignment in adolescents. However, maintaining these improvements during ongoing growth requires continued neuromuscular adaptation and long-term adherence to rehabilitation programs. Further research is needed to determine whether early posture correction interventions can produce lasting musculoskeletal benefits.

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