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Research article

Effects of a School-Based Multimodal Postural Education and Corrective Exercise Program on Spinal Alignment and Balance in School-Age Children

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Abstract: Postural deviations such as forward head posture and excessive thoracic kyphosis are increasingly reported in school-age children and are associated with sedentary behaviours and digital device use. Evidence for school-based multimodal interventions that simultaneously target postural alignment and functional outcomes in children remains limited, and few studies have evaluated such programs in real-world school settings. This prospective, quasi-experimental, single-group pre–post intervention study (without a control group) included 203 school-age children aged 6–13 years (mean age 9.37 ± 2.14 years) who participated in an 8-week school-based postural education and corrective exercise program (two sessions/week). Outcomes assessed at baseline and post-intervention included craniovertebral angle (CVA), thoracic kyphosis angle, lumbar lordosis angle, and static balance performance using the Romberg test with eyes open (EO). Pre–post changes were analysed using paired t-tests and effect sizes (Cohen's d). Significant improvements were observed in all outcomes following the intervention. The CVA increased ($\Delta = +2.92°$, $p < 0.001$, Cohen's $d = 0.63$), while thoracic kyphosis ($\Delta = -3.94°$, $p < 0.001$, $d = 0.62$) and lumbar lordosis angles decreased ($\Delta = -3.07°$, $p < 0.001$, $d = 0.59$). Static balance performance improved significantly (Romberg EO: $\Delta = +3.74$ s, $p < 0.001$, $d = 0.59$). A structured, school-based postural education and corrective exercise program can effectively improve sagittal spinal alignment and static balance in school-age children. Integrating posture-focused interventions into regular school activities may represent a feasible preventive strategy to address posture-related adaptations in contemporary paediatric populations. However, the absence of a control group limits causal inference and should be considered when interpreting these findings.

Keywords: balance, children, craniovertebral angle, forward head posture, posture, postural education, school-based intervention, spinal alignment

1. Introduction

Postural deviations in school-age children have become an increasing public health concern, with forward head posture, excessive thoracic kyphosis, and altered global spinal alignment frequently reported in contemporary paediatric populations [1,2]. These postural alterations are associated with prolonged sitting, reduced physical activity, and increased exposure to digital devices such as smartphones, tablets, and laptops, which promote sustained flexed head and trunk positions during learning and leisure activities. Early-life postural adaptations may persist into adolescence and adulthood, potentially contributing to musculoskeletal discomfort, reduced postural control, and impaired movement efficiency later in life [3-5].

Recent literature highlights a growing prevalence of forward head posture and sagittal spinal misalignments in children and adolescents, with several studies linking increased screen time and sedentary behaviour to altered cervical and thoracic alignment. Forward head posture, commonly quantified using the craniovertebral angle (CVA), has been associated with changes in cervical muscle activation patterns, reduced deep cervical flexor endurance, and compensatory thoracic kyphosis. These biomechanical alterations may affect global spinal alignment and sensorimotor integration, with potential consequences for postural stability and balance performance [6-8].

Corrective exercise programs targeting postural dysfunction have demonstrated beneficial effects in adult and adolescent populations, particularly when combining deep cervical flexor activation, stretching of shortened anterior musculature, scapular stabilization, and thoracic extension exercises. School-based interventions integrating postural education with structured exercise routines have been proposed as practical strategies for improving postural habits and musculoskeletal health in children [9,10].

A growing body of literature has reviewed postural disorders and corrective strategies in paediatric populations, emphasizing the importance of early identification and intervention to mitigate sagittal misalignments and related functional impairments. For example, comparative reviews of postural disorders and corrective interventions in children highlight the theoretical underpinnings of sagittal alignment, the influence of postural deviations on musculoskeletal health, and the potential efficacy of targeted programs in school and clinical settings [11].

However, the existing evidence remains heterogeneous with respect to intervention content, duration, and outcome measures, and relatively few studies have evaluated school-based multimodal programs that simultaneously assess objective postural parameters alongside functional outcomes such as balance performance [12-14]. Despite increasing recognition of posture-related musculoskeletal adaptations in children, there is a lack of well-documented school-based multimodal intervention studies that simultaneously examine changes in CVA, sagittal spinal curvatures (thoracic kyphosis and lumbar lordosis), and functional postural control within the same paediatric cohort, **particularly in real-world school** settings [15,16]. Addressing this gap is essential for informing preventive strategies that are feasible within educational environments and relevant to contemporary lifestyle factors [17-19]. To date, no school-based multimodal intervention studies have comprehensively evaluated both objective postural outcomes and functional balance outcomes within the same paediatric cohort.

The aim of this study was to evaluate the effects of a structured school-based postural education and corrective exercise program on forward head posture (quantified by CVA), thoracic kyphosis, lumbar lordosis, and static balance performance in school-age children [20-22].

By integrating objective postural measures with functional balance assessment in a relatively large school-based sample, the present study contributes evidence on the effectiveness of a feasible, multimodal intervention designed to address posture-related adaptations in children exposed to high levels of sedentary behaviour and digital device use [23,24]. The findings may inform the development of early preventive strategies for promoting musculoskeletal health during critical periods of growth and development [25,26].

2. Results

2.1. Prevalence of postural deviations at baseline and follow-up

At baseline (T0), a high prevalence of postural deviations was observed among the evaluated children. Anterior head projection was identified in 153 participants (75.4%), accentuated thoracic kyphosis in 132 participants (65.0%), shoulder asymmetry in 82 participants (40.4%), and incorrect global posture in 172 participants (84.7%).

Following completion of the intervention program (T1), the prevalence of all assessed postural deviations decreased. Anterior head projection was observed in 61 participants (30.0%), accentuated thoracic kyphosis in 50 participants (24.6%), shoulder asymmetry in 32 participants (15.8%), and incorrect global posture in 71 participants (35.0%). The pre- and post-intervention frequencies of postural deviations are summarized in Table 1.

Table 1. Prevalence of postural deviations at baseline (T0) and follow-up (T1) (N = 203)

Postural deviation	Baseline (T0) n (%)	Follow-up (T1) n (%)	Difference (T1–T0)
Anterior head projection	153 (75.4)	61 (30.0)	−92
Accentuated thoracic kyphosis	132 (65.0)	50 (24.6)	−82
Shoulder asymmetry	82 (40.4)	32 (15.8)	−50
Incorrect global posture	172 (84.7)	71 (35.0)	−101

2.2. Baseline characteristics

The study group consisted of 203 school-age students aged 6–13 years (mean age 9.37 ± 2.14 years), corresponding predominantly to a primary-school population. Demographic and device-use characteristics of the participants are presented in Table 2.

As shown in Table 2, the sample included 115 females (56.7%) and 88 males (43.3%). Regarding family structure, 127 participants (62.6%) came from biparental families, while 76 participants (37.4%) were from monoparental households.

With respect to digital device use, smartphone use was reported by 174 students (85.7%). Laptop use was reported by 55 participants (27.1%), and tablet use by 28 participants (13.8%). Several participants reported the use of more than one type of digital device.

Overall, the baseline characteristics indicate a heterogeneous school-based population with high exposure to digital devices, as summarized in Table 2.

Table 2. Baseline demographic and device-use characteristics of the study group (N = 203)

Variable	n (%) or Mean ± SD
Age (years)	9.37 ± 2.14
Sex	
Female	115 (56.7)
Male	88 (43.3)
Family structure	
Monoparental	76 (37.4)
Biparental	127 (62.6)
Device use	
Smartphone	174 (85.7)
Laptop	55 (27.1)
Tablet	28 (13.8)

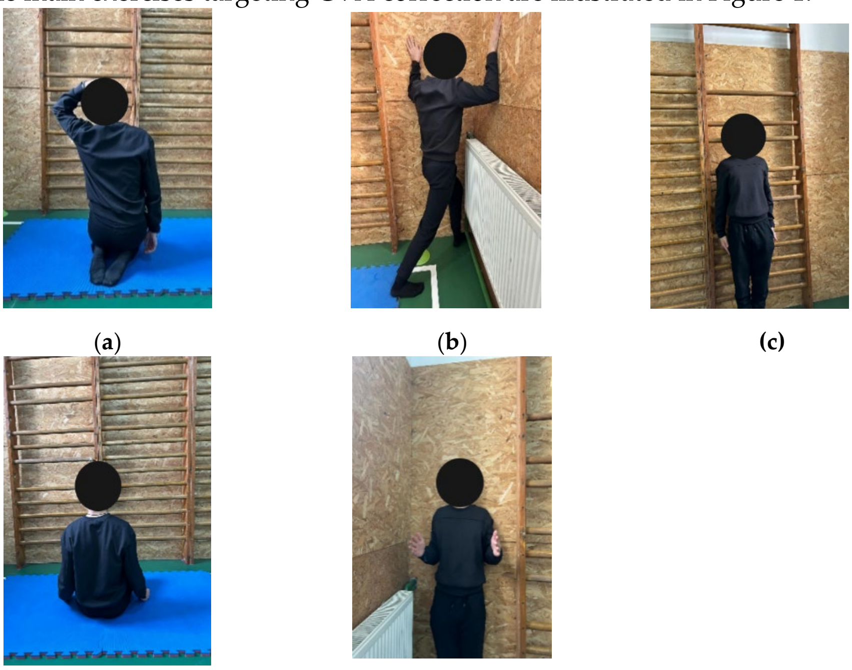
2.3. Kinetotherapeutic program

The kinetotherapeutic program was designed to address anterior head projection and associated cervical–scapular dysfunction through a combination of stretching, activation, and postural re-education exercises. The program targeted both shortened muscle groups and weakened stabilizers involved in forward head posture and altered cervical alignment.

Stretching exercises for the upper trapezius and levator scapulae were included to reduce cervical muscle tension that contributes to compensatory head positioning. Pectoral muscle stretching was implemented to correct anteriorized shoulder posture, facilitating repositioning of the head closer to the trunk axis. Activation of the deep cervical flexor muscles was achieved primarily through the chin tuck exercise, which aimed to restore neutral head alignment and improve cervical neuromuscular control.

Scapular stabilization exercises, including scapular retraction and wall angels, were incorporated to enhance shoulder girdle stability and reduce anterior shoulder displacement. These exercises support improved head–neck alignment by promoting coordinated cervical–thoracic–scapular interaction. Together, these components formed the basis of the intervention strategy for correcting forward head posture and improving CVA.

The main exercises targeting CVA correction are illustrated in Figure 1.



(**a**) (**b**) **(c)** **(d)** **(e)**

Figure 1. Corrective exercises targeting CVA: (a) upper trapezius stretching; (b) pectoral stretching; (c) chin tuck exercise; (d) scapular retraction exercise; (e) wall angels.

To address excessive thoracic kyphosis, the intervention program included exercises aimed at improving thoracic extension, correcting shoulder position, and strengthening the posterior trunk musculature. Pectoral stretching was emphasized to open the thoracic region and reduce the anterior shoulder posture that contributes to increased thoracic curvature. By decreasing anterior soft-tissue tightness, this exercise facilitates a more upright thoracic alignment.

Wall angel exercises were incorporated to promote active thoracic extension and improve scapular positioning against the thoracic wall, supporting progressive correction of kyphotic posture. In addition, the Superman exercise was used to activate the trunk extensor muscles, particularly at the thoracic level, contributing to improved postural endurance and reduction of excessive thoracic kyphosis.

The main exercises targeting thoracic kyphosis correction are illustrated in Figure 2.

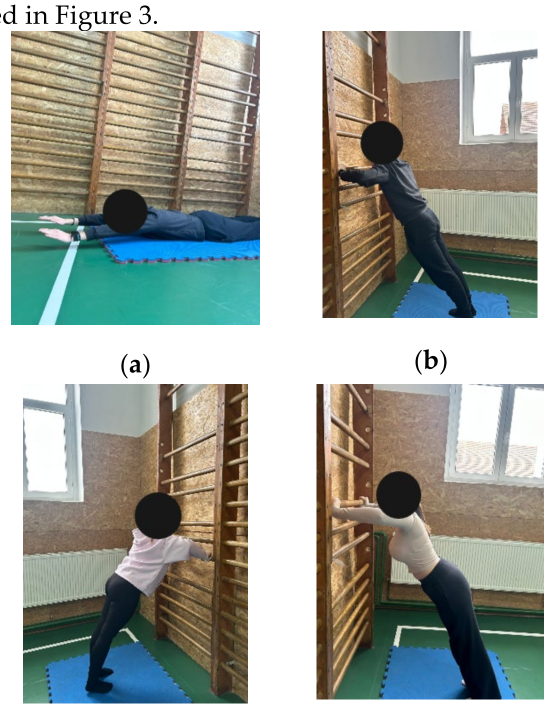
(**a**) (**b**) (**c**)

Figure 2. Corrective exercises targeting thoracic kyphosis: (a) pectoral stretching; (b) wall angels; (c) Superman exercise.

Correction of global postural alignment was addressed through exercises targeting the entire postural chain. A posture characterized by anterior head projection and anteriorized shoulders can alter spinal load distribution and lead to compensatory changes in lumbar lordosis. Therefore, the intervention included exercises aimed at improving trunk extensor control, postural awareness, and global spinal stability.

Wall-based alignment exercises, including prone trunk extension and wall-supported postural alignment drills, were used to enhance activation of the posterior muscle chain and promote maintenance of a balanced upright posture. These exercises facilitate coordinated activation of cervical, thoracic, and trunk stabilizing muscles, contributing to improved control of sagittal spinal alignment and potential stabilization of lumbar lordosis values.

The exercises targeting global postural alignment and lumbar lordosis stabilization are illustrated in Figure 3.



(**a**) (**b**) (**c**) (**d**)

Figure 3. Exercises targeting global postural alignment and lumbar lordosis stabilization: (a) prone trunk extension (Superman exercise); (b–d) wall-supported postural alignment exercises emphasizing posterior chain activation and trunk stability.

2.4. Effectiveness of postural education and corrective exercises

The effectiveness of the postural education and corrective exercise program was evaluated using a pre–post intervention design based on objective postural and functional parameters. Outcome measures included the CVA, thoracic kyphosis angle, lumbar lordosis angle, and static balance performance assessed by the Romberg test with eyes open (EO).

All parameters were assessed at baseline (T0) and after completion of the intervention program (T1). Comparisons between pre- and post-intervention values were performed using paired t-tests. The results are summarized in Table 3.

Following the intervention, statistically significant improvements were observed across all assessed outcomes (Table 3). The CVA showed a significant increase, while thoracic kyphosis and lumbar lordosis angles demonstrated significant reductions. Static balance performance also improved significantly, as reflected by increased Romberg EO time (all $p < 0.001$).

Table 3. Pre- and post-intervention comparison of postural and balance outcomes (N = 203)

Outcome	Pre-intervention (T0) Mean ± SD	Post-intervention (T1) Mean ± SD	Mean change (Δ)	Cohen's d	p-value
CVA (°)	43.06 ± 4.55	45.98 ± 4.75	+2.92	0.63	<0.001
Thoracic kyphosis angle (°)	42.75 ± 6.06	38.82 ± 6.55	−3.94	0.62	<0.001
Lumbar lordosis angle (°)	34.84 ± 5.04	31.78 ± 5.27	−3.07	0.59	<0.001
Romberg EO (s)	21.35 ± 6.20	25.09 ± 6.46	+3.74	0.59	<0.001

The CVA increased significantly from 43.06 ± 4.55° at baseline (T0) to 45.98 ± 4.75° at follow-up (T1), corresponding to a mean increase of 2.92° ($p < 0.001$). The pre- and post-intervention distributions of CVA values are illustrated in Figure 4.

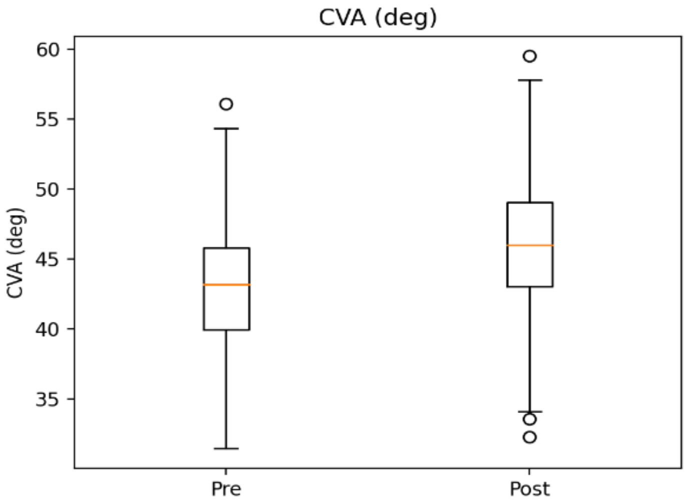


Figure 4. CVA values before (Pre) and after (Post) the intervention program.

A significant decrease in the thoracic kyphosis angle was observed following the intervention, with values decreasing from 42.75 ± 6.06° at baseline (T0) to 38.82 ± 6.55° at follow-up (T1). This corresponded to a mean reduction of 3.94° ($p < 0.001$). The distributions of thoracic kyphosis angle before and after the intervention are shown in Figure 5.

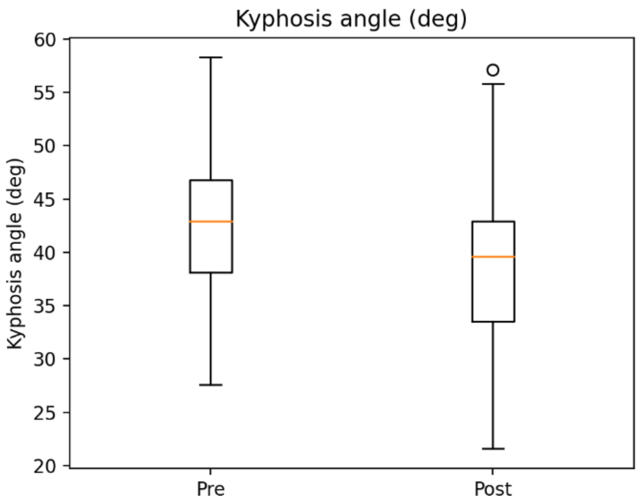


Figure 5. Thoracic kyphosis angle values before (Pre) and after (Post) the intervention program.

The lumbar lordosis angle also decreased significantly, from 34.84 ± 5.04° at baseline (T0) to 31.78 ± 5.27° at follow-up (T1), corresponding to a mean reduction of 3.07° ($p < 0.001$). The pre- and post-intervention distributions of lumbar lordosis angle are illustrated in Figure 6.

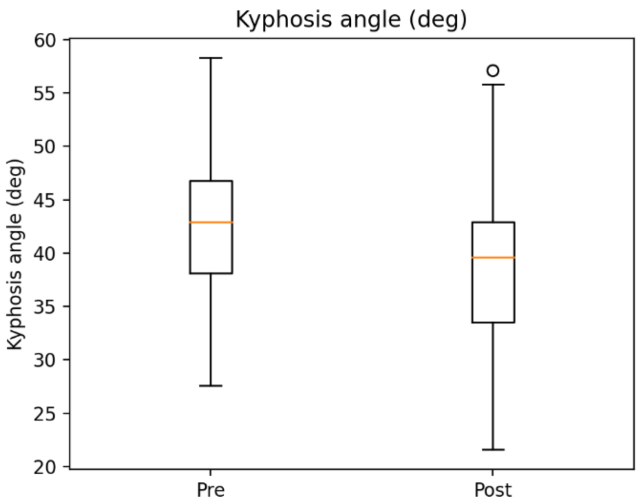


Figure 6. Lumbar lordosis angle values before (Pre) and after (Post) the intervention program.

Static balance performance improved significantly following the intervention. Romberg test performance with EO increased from 21.35 ± 6.20 s at baseline (T0) to 25.09 ± 6.46 s at follow-up (T1), corresponding to a mean increase of 3.74 s ($p < 0.001$). The distributions of Romberg EO values before and after the intervention are shown in Figure 7.

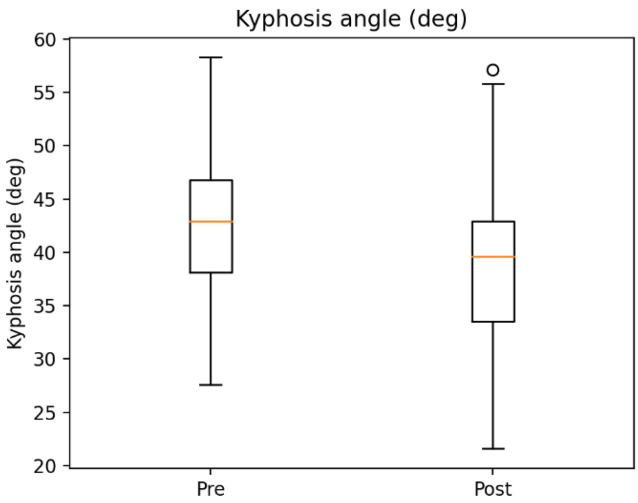


Figure 7. Romberg test performance with EO before (Pre) and after (Post) the intervention program.

3. Discussion

3.1. Effects of the Intervention on Forward Head Posture

The present study demonstrated a significant increase in the CVA following the postural education and corrective exercise program, indicating a clinically meaningful reduction in forward head posture. This finding supports the primary hypothesis and suggests that school-based corrective interventions can effectively improve cervical alignment in children. Given the high prevalence of forward head posture observed at baseline and the widespread use of digital devices in this population, the observed CVA improvement is particularly relevant for counteracting posture-related adaptations associated with prolonged screen exposure and sedentary behaviours [27].

The improvement in CVA is consistent with previous studies reporting that targeted activation of the deep cervical flexors (e.g., chin tuck), combined with stretching of shortened cervical and pectoral muscles and scapular stabilization exercises, leads to improved head–neck alignment and postural control. Multimodal exercise approaches appear to enhance neuromuscular coordination of the cervical–scapular region and promote more neutral head positioning during standing and functional tasks, which may explain the magnitude of change observed in the present sample [28].

The magnitude of the observed effects in the present study (Cohen's d ≈ 0.59–0.63 across postural and balance outcomes) is comparable to effect sizes reported in previous school- or clinic-based corrective exercise interventions targeting postural alignment in paediatric and adolescent populations, which have typically ranged from small-to-moderate to moderate effects. Studies employing multimodal exercise approaches integrating postural education, stretching, and stabilization exercises have reported similar improvements in CVA and sagittal spinal alignment over intervention periods of 6–12 weeks [29,30]. These comparisons suggest that the present school-based program achieved clinically meaningful changes of a magnitude consistent with the existing literature, despite being delivered in a real-world educational setting.

3.2. Effects on Sagittal Spinal Alignment (Thoracic Kyphosis and Lumbar Lordosis)

In line with the second hypothesis, significant reductions in thoracic kyphosis and lumbar lordosis angles were observed after the intervention. Excessive thoracic kyphosis and altered lumbar curvature are commonly reported in children with prolonged sitting habits, poor ergonomics, and low levels of physical activity. The present findings indicate that targeted postural exercises focusing on thoracic extension, posterior chain activation, and global alignment can positively influence sagittal spinal curvature patterns in school-age children [31].

From a biomechanical perspective, reductions in thoracic kyphosis may be explained by improved extensibility of anterior soft tissues, such as the pectoral muscles, and increased activation and endurance of thoracic extensor musculature. The concurrent decrease in lumbar lordosis may reflect improved trunk and lumbopelvic control, supporting the concept of interdependence within the kinetic chain, whereby correction at one spinal segment contributes to improved global sagittal alignment. Similar improvements in spinal posture following school-based corrective exercise programs have been reported in paediatric populations, reinforcing the value of early posture-oriented interventions [32].

3.3. Effects on Static Balance Performance

Consistent with the third hypothesis, static balance performance assessed by the Romberg test with EO improved significantly following the intervention. Although the Romberg test represents a basic clinical measure of balance, the observed improvement suggests enhanced postural stability and neuromuscular control. Altered cervical and trunk posture has been associated with changes in proprioceptive input and sensorimotor integration, including disruptions in cervical afferentation and vestibulo-spinal interactions, which may negatively affect balance performance. Therefore, improvements in postural alignment may indirectly contribute to enhanced postural control during quiet standing by improving the quality of proprioceptive input and central sensorimotor integration [33].

The relationship between posture and balance is increasingly recognized in paediatric populations, with evidence indicating that forward head posture and excessive thoracic kyphosis may impair proprioceptive processing and postural responses. By improving head, trunk, and scapular alignment, the intervention may have optimized afferent input from cervical and paraspinal musculature and facilitated more efficient sensorimotor integration and motor responses for maintaining upright stance. These findings suggest that posture-focused exercise programs may confer functional benefits beyond structural alignment, contributing to improved balance and movement efficiency in daily activities and sports participation [34].

Our findings are consistent with previous theoretical and empirical work emphasizing the role of early postural correction in paediatric populations. Comparative literature on postural disorders and corrective strategies underscores the potential benefits of interventions focused on sagittal alignment and neuromuscular control, supporting the rationale for school-based multimodal programs [11].

3.4. Clinical and Public Health Implications in the Context of Digital Device Use

The high prevalence of forward head posture, thoracic kyphosis, and incorrect global posture observed at baseline reflects contemporary trends reported in paediatric populations, in which prolonged screen time, increased use of smartphones and tablets, and sedentary behaviours are associated with postural deviations. The significant post-intervention improvements observed in the present study highlight the potential of school-based postural education and corrective exercise programs as practical, low-cost strategies to counteract posture-related musculoskeletal risk factors linked to digital device use [35].

From a clinical perspective, early identification and correction of postural deviations may help prevent the progression of maladaptive postural patterns and reduce the risk of future musculoskeletal discomfort or dysfunction during adolescence and adulthood. Integrating simple screening tools (e.g., CVA assessment, observation of sagittal spinal curves) and short corrective exercise routines into school health programs or routine paediatric assessments could facilitate early intervention in at-risk children. Such preventive approaches are particularly relevant given the increasing exposure of children to non-ergonomic device use in both educational and recreational contexts [36].

At the public health level, incorporating posture education and movement-based interventions into school curricula may contribute to healthier postural habits and increased awareness of ergonomics during digital device use. Educational strategies targeting children, parents, and teachers regarding appropriate screen positioning, sitting posture, and the importance of regular movement breaks may complement exercise-based interventions and help mitigate the long-term musculoskeletal consequences of sedentary, screen-dominated lifestyles [37].

3.5. Limitations of the Study

Several limitations of the present study should be acknowledged. First, the single-arm pre–post design without a control group limits causal inference regarding the observed improvements, as changes over time cannot be fully attributed to the intervention alone. Second, the relatively short intervention period and lack of long-term follow-up preclude conclusions regarding the durability of postural improvements and whether the observed changes are maintained over time without continued supervision or reinforcement [38].

In addition, although standardized assessment procedures were used, postural measurements such as CVA and spinal curvature angles may be influenced by examiner-related variability and participant positioning, which may introduce measurement error. The use of clinical postural assessment methods rather than more advanced imaging or motion analysis techniques may limit the precision of curvature quantification. Furthermore, potential confounding factors such as daily screen time, physical activity levels outside the intervention sessions, and adherence to postural recommendations were not objectively monitored and may have influenced the observed outcomes. Furthermore, potential confounding factors such as body mass index (BMI), daily screen time, baseline physical activity levels outside the intervention sessions, and adherence to postural recommendations were not systematically assessed or controlled for and may have influenced the observed outcomes [39].

3.6. Future Directions

Future research should employ randomized controlled designs to strengthen causal inference regarding the effectiveness of postural education and corrective exercise programs in paediatric populations. Including a non-intervention control group or alternative intervention group would allow for more robust comparisons and clearer attribution of observed changes to the intervention itself. Longer follow-up periods are also needed to evaluate the sustainability of postural improvements and to determine whether periodic reinforcement sessions are required to maintain benefits over time [40].

Further studies should explore the dose–response relationship of postural interventions, including optimal program duration, frequency, and exercise selection, as well as the added value of home-based components or digital health tools (e.g., posture reminders, app-based exercise guidance). Investigating the interaction between posture correction programs and lifestyle factors such as daily screen time, physical activity levels, and ergonomic education may provide insights into comprehensive, multicomponent strategies for promoting musculoskeletal health in children [41].

In addition, future studies with larger samples should examine whether intervention effects differ by sex and baseline posture severity to identify subgroups that may benefit most from school-based postural programs.

Emerging digital and Artificial Intelligence (AI)-assisted posture assessment tools may offer new opportunities for objective, scalable, and automated screening in school-based settings. Recent work has explored the use of AI-based photogrammetric systems and mobile solutions that leverage algorithms to detect postural deviations from images or video input. These technologies could reduce reliance on manual landmarking and specialized equipment, increase throughput, and support longitudinal monitoring. However, challenges remain, including the need for rigorous validation against gold-standard clinical measures, considerations of privacy and data security when capturing and processing student images, and the requirement for appropriate training and oversight in real-world educational environments. We consider that integrating AI-assisted posture analysis in future studies may enhance both efficiency and objectivity of assessment, but must be accompanied by careful evaluation of accuracy, ethical use, and feasibility in school settings [42,43].

4. Materials and Methods

4.1. Study design

This study employed a prospective, quasi-experimental, single-group pre–post intervention design without a control group to evaluate the effects of a postural education and corrective exercise program on postural alignment and static balance in school-age children. The study was not randomized and did not include a comparator group. Assessments were performed at baseline (T0) and after completion of the intervention period (T1). Primary outcomes included CVA, thoracic kyphosis angle, lumbar lordosis angle, and Romberg test performance with EO.

4.2. Study setting and participants

The study was conducted in a school-based setting in Romania between December 2024 and December 2025. Participants were recruited from local primary schools and took part in a structured postural education and corrective exercise program delivered within the context of regular school activities. The exact number of participating schools was not systematically recorded; however, recruitment was conducted across multiple local primary schools within Arad County.

A total of 532 school-age children were assessed for eligibility, of whom 329 did not meet the inclusion criteria or declined participation. Consequently, 203 children were enrolled and completed both baseline (T0) and post-intervention (T1) assessments, corresponding to a response rate of 38.2%. The sample predominantly represented primary school–aged children, with a smaller proportion of early adolescents, which is relevant for interpreting posture and balance outcomes in the context of developmental stage.

All participants were apparently healthy at the time of enrolment and able to engage in physical exercise. Assessments and intervention sessions were conducted in a standardized setting under professional supervision, with clinical oversight provided by collaborating medical rehabilitation centres in Arad, Romania, including Izvorul Sănătății Medical Center, DALIA Pediatric Rehabilitation Center, and Info-Medica Clinic.

Participation in the study was voluntary, and written informed consent was obtained from parents or legal guardians prior to inclusion.

4.3. Inclusion and exclusion criteria

Children were eligible for inclusion if they were of school age, enrolled in participating primary or middle schools, and able to participate in physical exercise. Eligibility further required availability for both pre-intervention (T0) and post-intervention (T1) assessments, completion of the full postural assessment protocol—including CVA, thoracic kyphosis angle, lumbar lordosis angle, and the Romberg test with EO—and the provision of written informed consent from parents or legal guardians, along with participant assent.

Exclusion criteria included the presence of acute neck or back pain limiting participation in evaluation or exercise, diagnosed neurological disorders, musculoskeletal conditions requiring ongoing medical or physiotherapeutic treatment, or acute injuries that could compromise safe participation. Children were also excluded if they had incomplete datasets, defined as missing pre- or post-intervention measurements for the primary outcomes, inability to complete the postural assessment or Romberg test, or withdrawal of consent at any point during the study.

The selection process and participant flow according to the applied inclusion and exclusion criteria are illustrated in Figure 8.

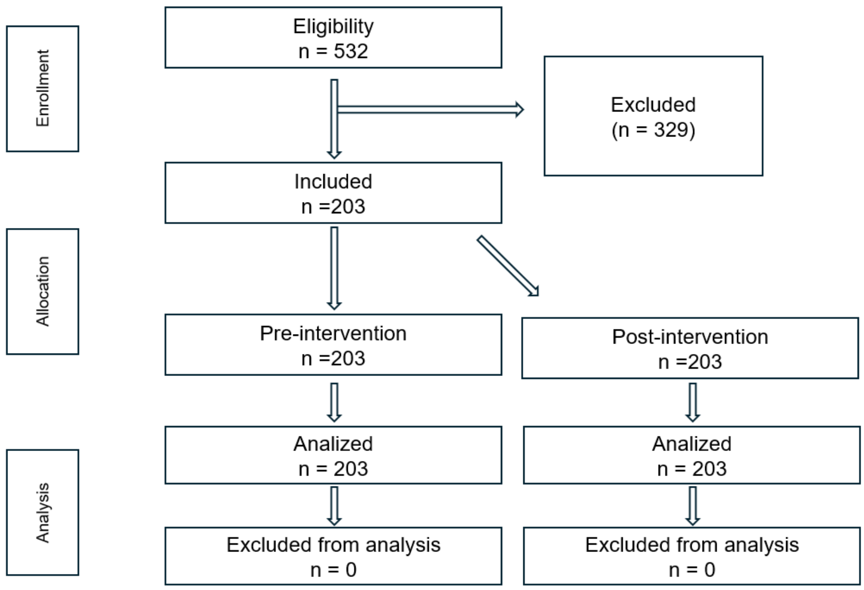


Figure 8. Distribution of students according to the applied inclusion and exclusion criteria.

4.4. Intervention protocol

The postural education and corrective exercise program was implemented over an 8-week period and was delivered within the school setting as part of organized physical activity sessions. Exercise sessions were conducted two times per week, with each session lasting approximately 30–40 minutes.

In addition to the exercise-based intervention, participants received structured postural education integrated into each session. The educational content focused on (i) basic spine anatomy and neutral posture concepts; (ii) identification of common postural deviations (e.g., forward head posture, rounded shoulders, excessive thoracic kyphosis); (iii) ergonomic principles for sitting, desk work, and digital device use (e.g., screen height, viewing distance, sitting posture); and (iv) the importance of regular movement breaks and posture awareness during daily activities.

The postural education component was delivered in brief interactive segments (approximately 5–10 minutes) at the beginning of selected sessions using age-appropriate explanations, demonstrations, and visual cues. Education was provided by trained kinetotherapists who also supervised the exercise sessions. To reinforce learning, children were given simple verbal reminders and practical cues during exercises and daily school activities. No written materials or digital resources were distributed as part of the intervention.

The intervention consisted of a structured set of exercises targeting cervical, thoracic, and lumbopelvic alignment, as well as scapular stabilization and postural control. Exercises included stretching of shortened muscle groups (upper trapezius, levator scapulae, and pectoral muscles), activation of deep cervical flexors through chin tuck exercises, scapular stabilization exercises (scapular retraction and wall angels, a shoulder mobility exercise performed with the back and arms against the wall), thoracic extension and trunk extensor activation exercises (including the Superman exercise), and global postural alignment exercises performed against the wall.

All exercise sessions were supervised by trained kinetotherapists, with emphasis placed on correct execution, controlled movement, and maintenance of proper postural alignment throughout each exercise. Exercise difficulty and volume were adapted to the age and physical capacity of the participants to ensure safety and adherence.

Participants were instructed to perform the exercises in a slow and controlled manner, with attention to breathing and posture awareness. No additional home-based exercise program was prescribed during the intervention period.

4.5. Outcome measures

Postural alignment and static balance were assessed using objective clinical and postural parameters. All outcome measures were recorded at baseline (T0) and after completion of the intervention program (T1) by trained assessors using standardized assessment procedures.

4.5.1. Craniovertebral angle

Forward head posture was quantified using the CVA obtained from standardized lateral digital photographs. CVA was defined as the angle formed between a horizontal line passing through the spinous process of the seventh cervical vertebra (C7) and a line connecting C7 to the tragus of the ear. Lower CVA values indicate greater anterior head projection.

Photographs were taken with participants standing barefoot in a relaxed, habitual posture, with the camera positioned at shoulder height and at a fixed distance from the participant. Anatomical landmarks (tragus and C7) were visually identified, and CVA was calculated using image analysis software (ImageJ, version 1.54f; National Institutes of Health, Bethesda, MD, USA). All measurements were performed by the same assessor at T0 and T1 to reduce inter-rater variability.

4.5.2. Thoracic kyphosis angle

Thoracic kyphosis was assessed by measuring the sagittal curvature of the thoracic spine using a handheld digital inclinometer (Baseline® Digital Inclinometer; Fabrication Enterprises Inc., White Plains, NY, USA). Measurements were performed in an upright standing position. The inclinometer was positioned over standardized anatomical landmarks at the upper thoracic (T1–T2) and lower thoracic (T12–L1) segments, and the thoracic kyphosis angle was calculated as the sum of the two segmental inclination values. Greater values reflected increased thoracic curvature. Two consecutive measurements were obtained and averaged for analysis. All measurements were performed by the same trained assessor at T0 and T1 to reduce inter-rater variability.

4.5.3. Static balance assessment

Static balance performance was assessed using the Romberg test with EO. Participants were instructed to stand barefoot with feet together and arms alongside the body while maintaining an upright posture. The duration for which balance could be maintained without postural sway or stepping was recorded in seconds.

4.5.4. Lumbar lordosis angle

Lumbar lordosis was evaluated by measuring the sagittal curvature of the lumbar spine in the standing posture using the same handheld digital inclinometer as for thoracic kyphosis assessment (Baseline® Digital Inclinometer; Fabrication Enterprises Inc., White Plains, NY, USA). The inclinometer was positioned over standardized anatomical landmarks at the thoracolumbar junction (T12–L1) and lumbosacral junction (L5–S1). The lumbar lordosis angle was calculated as the sum of the two segmental inclination values, with greater values indicating increased lumbar curvature. Two consecutive measurements were obtained and averaged for analysis. All measurements were performed by the same trained assessor at T0 and T1 to reduce inter-rater variability.

All postural and balance measurements were performed by the same trained assessor at both time points. Due to the nature of the school-based intervention, assessor blinding to time point was not feasible. Formal intra-rater or inter-rater reliability testing was not conducted within the present study; however, standardized protocols and repeated measurements were used to minimize measurement error.

4.6. Statistical analysis

Statistical analysis was performed using standard descriptive and inferential methods. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were summarized as absolute frequencies and percentages.

Pre- and post-intervention comparisons of continuous outcome measures, including CVA, thoracic kyphosis angle, lumbar lordosis angle, and Romberg test performance with EO, were conducted using paired t-tests. Effect sizes were calculated using Cohen's d to estimate the magnitude of intervention-related changes.

All statistical tests were two-tailed, and the level of statistical significance was set at $p < 0.05$. Statistical analyses were performed using JASP 0.19.1 (University of Amsterdam, Amsterdam, The Netherlands).

4.7. Ethical approval.

Ethical approval for this study was obtained from the Research Ethics Committee of the Faculty of Medicine and Pharmacy, University of Oradea (Approval No. CEFMF/1, 27 June 2024). In addition, site-level administrative approvals were granted by each participating rehabilitation clinic: Izvorul Sănătății Medical Center (Approval No. 512/11 November 2024), DALIA Pediatric Rehabilitation Center (Approval No. 1026/09 December 2024), and InfoMedica Clinic (Approval No. 148/1, 08 February 2024).

The study was conducted in accordance with the principles of the Declaration of Helsinki. Participation in the study was voluntary. Written informed consent was obtained from the parents or legal guardians of all participants, and assent was obtained from the children where applicable.

4.8. Hypothesis of the study

Based on current evidence regarding posture-related musculoskeletal adaptations in children and the reported effectiveness of corrective exercise programs, we hypothesized that:

1. The implemented postural education and corrective exercise program would significantly increase the CVA, indicating a reduction in forward head posture;
2. Thoracic kyphosis and lumbar lordosis angles would decrease following the intervention;
3. Static balance performance, assessed by the Romberg test with EO, would improve after the intervention period.

5. Conclusions

This study demonstrated that a structured, school-based postural education and corrective exercise program can significantly improve postural alignment and static balance in school-age children. Significant increases in CVA indicated a reduction in forward head posture, while significant reductions in thoracic kyphosis and lumbar lordosis angles reflected improvements in sagittal spinal alignment. Improvements in static balance performance further suggest functional benefits of posture-focused interventions.

The high prevalence of postural deviations observed at baseline, in the context of widespread digital device use, highlights the relevance of early preventive and corrective strategies within school environments. The present findings support the feasibility and effectiveness of integrating targeted postural exercises and posture education into regular school activities as a practical approach to counteracting posture-related adaptations associated with sedentary behaviours.

By providing evidence from a school-based population in Romania, this study contributes region-specific data to the growing international literature on paediatric postural health and the effects of corrective exercise interventions. The results underscore the importance of early identification and intervention to promote healthy musculoskeletal development during critical periods of growth.

Future implementation of school-based postural programs, combined with ergonomic education for children, parents, and teachers, may represent a valuable public health strategy to reduce the long-term musculoskeletal consequences of poor posture in digitally engaged youth.

Although the observed changes in postural alignment and balance were modest in magnitude, they are likely to be meaningful in daily life, particularly in the context of early prevention. Small-to-moderate improvements in cervical and sagittal spinal alignment during childhood may reduce cumulative postural strain, improve movement efficiency, and support more stable postural control during routine activities and sports participation. Over the long term, early posture correction may contribute to reduced risk of musculoskeletal discomfort and postural dysfunction in adolescence and adulthood, especially when integrated into regular school-based health promotion programs.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Research Ethics Committee of the Faculty of Medicine and Pharmacy, University of Oradea (Approval No. CEFMF/1, 27 June 2024). In addition, site-level administrative approvals were obtained from the participating rehabilitation clinics: Izvorul Sănătății Medical Center (Approval No. 512/11 November 2024), DALIA Pediatric Rehabilitation Center (Approval No. 1026/09 December 2024), and InfoMedica Clinic (Approval No. 148/1, 08 February 2024).

Informed Consent Statement: Informed consent was obtained from the parents or legal guardians of all subjects involved in the study. Assent was obtained from the children where appropriate. Written informed consent was obtained from the parents or legal guardians to publish this paper.

Data Availability Statement: For ethical and privacy reasons related to research involving minors, the data underlying this study are not publicly available. Anonymized datasets may be obtained from the corresponding author upon reasonable request.

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