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Influence of physical exercise on postural alignment and walking patterns in primary education students

Abstract

Background: Physical activity is essential for developing neuromuscular function, posture, and gait in children and adolescents, while sedentary behaviors may impair musculoskeletal alignment and functional movement. Integrating structured exercise into school curricula can promote healthy physical development and movement competence.

Aim of study: This study aimed to investigate the effects of a 12-week structured physical activity program on gait, posture, and functional stability among primary school-aged children and adolescents.

Methods: One hundred forty-seven children were assigned to an experimental group undergoing a 12-week exercise program or a control group with regular activity. Assessments included Leonardo Mechanography, plantar pressure, G-sensor, and Posture Screen Mobile, measuring gait, posture, and BMI. Data was analyzed using paired t-tests, Wilcoxon tests, effect sizes (Cohen's d), and correlations ($p < 0.05$).

Findings: The experimental group exhibited significant improvements in walking speed (+0.13 m/s), step symmetry (+4%), postural sway (-0.7 cm SI), shoulder slope (-0.8°), and pelvic tilt (-1.4°), along with a modest reduction in BMI (-0.3 kg/m²). The control group showed minimal changes. These findings indicate that structured physical activity enhances neuromuscular coordination, gait efficiency, and postural alignment. The integrated use of biomechanical and postural assessment tools allowed for multidimensional evaluation of functional improvements, reinforcing the positive impact of targeted exercise interventions on musculoskeletal health in children.

Conclusions: Structured, moderate-intensity physical activity effectively enhances gait, posture, and functional stability in primary school children and adolescents. Implementing such programs in schools promotes physical literacy, neuromuscular development, and long-term musculoskeletal health, offering evidence-based guidance for educators and policymakers.

Keywords: gait, musculoskeletal health, posture, physical activity, primary school children

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Abbreviations: BMI, body mass index; SI, sway index; WHO, world health organization, kPa, kilo Pascal; BTS, biomedical technology solutions

Introduction

Physical activity is a cornerstone of child development, influencing various aspects of health and well-being. In the context of primary education, integrating physical exercise into daily routines is essential for fostering optimal growth and development. Engaging in regular physical exercise has been shown to enhance postural alignment and walking patterns in children and adolescents. Physical activity encompasses bodily movements by skeletal muscles requiring energy, yet many children and adolescents lack adequate engagement in such activities.[1] Among the various benefits, physical activity has been shown to positively impact postural alignment and gait patterns, which are crucial for overall musculoskeletal health and functional movement.

Schoolbag carriage is essential for students, but excessive weight can lead to compromised posture, neuro-musculoskeletal disorders, reduced cardiopulmonary function, and pain in the shoulders, back, and hands.[2] Postural alignment refers to the positioning of the body's segments in relation to each other and the environment, while gait encompasses the manner or pattern of walking. Both are integral components of motor development and are indicative of a child's physical health and functional capabilities. Foundational motor skills in early childhood are crucial for physical, cognitive, and social development, serving as a base for more complex skills.[3] Proper postural alignment ensures efficient movement, reduces the risk of musculoskeletal disorders, and supports optimal organ function. Similarly, a well-coordinated gait pattern is essential for balance, mobility, and participation in various physical activities.

In contrast, poor posture and abnormal gait patterns can lead to a range of issues, including musculoskeletal pain, fatigue, and limitations in physical performance. These problems can persist in adolescence and adulthood if not addressed during formative years. Therefore, early intervention through physical activity is crucial for preventing and mitigating such issues. Engaging in regular physical exercise has been identified as a key factor in improving postural alignment and gait patterns in children. Studies have demonstrated that specific physical activities, such as strength training, balance exercises, and aerobic activities, can enhance muscle strength, flexibility, and coordination, all of which contribute to better posture and gait. A study found that physical activity practice positively influenced the postural control state of school children, highlighting the importance of regular exercise in maintaining proper posture.[4]

Similarly, an intervention study revealed that involving an 18-week exercise program integrated into physical education classes significantly improved the posture of young school-age pupils.[5] The program included activities aimed at strengthening core muscles and promoting body awareness, leading to noticeable improvements in postural alignment. Concerns regarding children's physical health, especially posture, have risen due to the association of poor posture with long-term issues such as back pain and spinal dysfunction. The increase in sedentary activities, primarily related to technology, worsens the situation. Introducing physical activity programs in schools could offer structured chances for children to enhance strength, flexibility, and body alignment.[6] Furthermore, another research indicated that low levels of physical activity and irregular postural habits were considered risk factors for developing scoliosis in schoolchildren.[7] The significance of postural health in primary-school-aged children is vital for their long-term well-being, influenced by physical changes, spinal development, puberty, and increased sedentary behavior. Back pain (BP) in children and adolescents is rising, moving from about 1% at age 7 to 12–40% by age 12, peaking at 39–71% during ages 12 to 15 due to puberty. By the end of adolescence, BP rates align with those of adults, and studies indicate that adolescent BP is a predictor of adult BP, highlighting the need to identify early risk factors.[8] A study reported a 27% prevalence of back pain in children aged 6 to 12, associated with excessive screen time and inadequate backpack designs, indicating the need for proper monitoring to prevent musculoskeletal issues.[9] This underscores the importance of promoting consistent physical activity and awareness of proper posture from an early age.[7] Modern technology may lead to poor posture due to decreased physical activity, resulting in muscle imbalances and spinal misalignment. Promoting physical activity is essential for health benefits, including lower mortality risks and enhanced mental health, rendering it a global health priority.[10]

The beneficial effects of physical activity on posture and gait can be attributed to several physiological mechanisms. Regular exercise enhances muscle strength and endurance, particularly in the core and lower extremities, which are vital for maintaining upright posture and efficient gait. Additionally, physical activity improves proprioception and neuromuscular coordination, leading to better balance and movement control. These improvements not only enhance posture and gait but also contribute to overall physical fitness and functional independence. Moreover, physical activity promotes bone health by increasing bone density and stimulating bone growth, which is crucial during the growth spurts characteristic of childhood and adolescence. Stronger bones provide better support for the musculoskeletal system, reducing the risk of postural deformities and gait abnormalities. A study found that higher levels of physical activity were related to lower postural sway and superior gait stability in children and adolescents, further emphasizing the role of physical activity in musculoskeletal health.[11]

Despite the well-documented benefits of physical activity, several challenges hinder its integration into primary education. Sedentary behaviors, such as prolonged screen time and lack of physical education programs, have become prevalent among children, leading to decreased opportunities for physical exercise. Additionally, environmental factors, including limited access to safe play areas and resources, can restrict children's participation in physical activities. Current gait technology, particularly instrumented gait mats, facilitates the collection and analysis of gait characteristics and symmetry in healthy school-aged children, enabling large-scale participation and multiple walking trials, thereby overcoming earlier research limitations.[12] Addressing these barriers requires a multifaceted approach involving policy changes, curriculum development, and community engagement. Schools play an important role in promoting physical activity by providing structured programs, encouraging active lifestyles, and educating students about the importance of physical health. Collaborations between educators, healthcare professionals, and families are essential to create supportive environments that facilitate regular physical activity.

This study aims to evaluate the influence of physical exercise on postural alignment and walking patterns in primary education students. By examining the effects of various physical activities, the research seeks to identify effective strategies for enhancing musculoskeletal health in children and adolescents within the primary education setting. The findings are expected to inform educational practices and policies, contributing to the development of programs that promote physical activity and improve postural and gait outcomes among primary school students.

Material and methods

Study Design

This study utilized a quasi-experimental pre-test and post-test design to investigate the effects of structured physical exercise on postural alignment and gait patterns in primary education students. Quasi-experimental design is a research methodology that integrates aspects of true experimental methods with observational studies, which is used when traditional experimental designs are impractical or unethical, acting as a bridge between these two approaches.[13]

Participants

A total of 147 school children aged 6–15 years were recruited from three primary schools. Inclusion criteria included being healthy, enrolled in regular physical education classes, and absence of musculoskeletal, neurological, or orthopedic disorders. Students with recent injuries, chronic illnesses, or prior surgeries affecting mobility were excluded. Written parental consent and child assent were obtained prior to participation.

Ethical considerations

This research was carried out in accordance with the ethical principles of the Declaration of Helsinki[14] and received ethical approval from the Institutional Ethics Committee of the Sports University of Tirana (Protocol No. 915/2, dated 14 May 2024). Prior to participation, both the participants and their parents were fully informed about the study's aims, procedures, potential risks, and anticipated benefits. All data were treated with strict confidentiality, and participants retained the right to withdraw from the study at any point without facing any adverse consequences.

Intervention

The intervention consisted of a 12-week structured physical exercise program, which was integrated into regular physical education classes. Sessions were conducted three times per week, each lasting 45 minutes. The program was designed to enhance multiple aspects of physical fitness and motor skills in children and adolescents. The exercises focused on core stabilization, including planks and bridges, to strengthen trunk muscles and improve postural control. Additionally, balance training was incorporated through single-leg stances and dynamic tasks, promoting stability and proprioceptive development. Functional strength exercises, such as squats and lunges, were included to enhance lower limb strength and muscular endurance. Finally, coordination and gait drills, including walking on lines and navigating obstacle courses, were implemented to improve motor coordination and walking patterns. The intensity of the program was moderate, aligned with the World Health Organization's physical

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activity guidelines for children (WHO, 2020), ensuring safety while providing sufficient stimulus for physiological and neuromuscular adaptations.

Instruments and Measurements

Postural control, functional muscle performance, and gait characteristics were comprehensively assessed using a combination of validated instruments. The Leonardo Mechanography platform recorded ground reaction forces to provide precise measures of balance, power, and postural sway, enabling detailed evaluation of neuromuscular function. The development of the musculoskeletal system in children and adolescents is significant in pediatric research due to the link between muscle force and bone diseases.[15] Simultaneously, plantar pressure analysis was conducted using Pedar system to quantify foot loading patterns, including peak plantar pressure, contact area, and center of pressure trajectory, allowing for assessment of gait stability and foot biomechanics. Plantar pressure assessment offers insights into foot dynamic loading and regional contact with the ground.[16]

Additionally, trunk and limb kinematics during gait were monitored with a wearable G-sensor inertial measurement unit (IMU), which captures acceleration, angular velocity, and orientation, providing parameters such as stride length, cadence, gait symmetry, and postural sway during walking.[17] Together, these instruments offered a multidimensional evaluation of physical function and movement patterns in children and adolescents. Furthermore, the study incorporated Posture Screen Mobile evaluations to assess postural alignment, including shoulder slope and pelvic tilt, adding a complementary dimension to the biomechanical data. The combined use of these tools allowed for the capture of multidimensional changes in movement patterns, postural alignment, and functional stability, offering objective evidence of improvements in walking speed, step symmetry, core stability, and postural sway following the structured physical activity intervention. This integrated approach enhanced the precision and reliability of measurements, providing a holistic understanding of how targeted exercise influences both static and dynamic postural control, ultimately supporting the conclusions that structured physical activity positively affects gait, posture, neuromuscular development, and overall functional outcomes in primary school-aged children and adolescents.

Procedure

The study was conducted in three sequential phases. During the baseline assessment (pre-test), anthropometric measurements including height, weight, and BMI were recorded, and posture and gait were evaluated using the Leonardo Mechanography platform, plantar pressure system, and G-sensor devices. Following this, participants engaged in a 12-week structured exercise intervention under the supervision of trained physical education teachers, with exercise intensity and adherence monitored through heart rate and step count data, while any adverse events were systematically documented. In the post-intervention assessment (post-test), all measures were repeated using identical protocols and devices to ensure consistency, allowing for direct comparison of pre- and post-intervention outcomes to evaluate the effects of the exercise program.

Statistical analysis

Data analysis was conducted using IBM SPSS Statistics Version 29, a widely recognized software for advanced statistical evaluation in clinical and educational research. Initially, descriptive statistics including means, standard deviations, and frequency distributions were calculated to provide a comprehensive overview of participants' demographic characteristics and baseline postural and gait parameters. Assessing the normality of continuous variables using the Shapiro-Wilk test ensured the selection of appropriate parametric or non-parametric tests, a standard procedure to maintain the validity of inferential analyses.[18] For variables meeting the assumption of normality, paired t-tests were employed to examine pre- and post-intervention differences, while Wilcoxon signed-rank tests were applied to non-normally distributed variables. To quantify the practical significance of observed changes, Cohen's d effect sizes were calculated, providing an estimate of the magnitude of intervention effects beyond statistical significance. Across all analyses, statistical significance was set at $p < 0.05$, aligning with conventional thresholds in biomedical and educational research to balance Type I and Type II error risks. This rigorous analytical approach ensures both the reliability and interpretability of the study's findings, allowing for meaningful conclusions regarding the effects of structured physical exercise on children's posture and gait.

Reliability and validity

The reliability and validity of the measurements were rigorously established to ensure accuracy and consistency. Posture assessments demonstrated excellent inter-rater and intra-rater reliability, with a two-way random effects intraclass correlation coefficient (ICC) exceeding 0.90.[19] Gait measurements obtained using video-based software were validated against gold-standard motion capture systems, confirming their precision for biomechanical analysis. 3D gait analysis employs biomechanics and advanced technology for assessing gait dynamics but is restricted to certain medical centers due to high costs and specialized technician needs.[20] All data were anonymized and securely stored on password-protected computers, with access restricted to the research team, and backup copies maintained to safeguard against data loss, ensuring robust data management and confidentiality throughout the study.

Results

Table 1 presents the pre- and post-test values of Body Mass Index (BMI) for both the control and experimental groups. The control group exhibited a pre-test BMI of 18.5 kg/m², which slightly increased to 18.6 kg/m² post-intervention, corresponding to a minimal change of +0.1 kg/m². In contrast, the experimental group, which participated in a structured physical activity program, showed a decrease from 18.2 kg/m² to 17.9 kg/m², representing a -0.3 kg/m² change. Statistical analysis using a paired t-test revealed that the BMI change in the experimental group was statistically significant ($t = 2.45$, $p = 0.018$), while the change in the control group was not significant ($t = 0.72$, $p = 0.48$). The effect size, calculated using Cohen's d, was 0.56 for the experimental group, indicating a moderate effect of the intervention on BMI.[21] These findings suggest that participation in structured physical activity over the study period resulted in measurable improvements in body composition among primary school students.

Table 2 displays the pre- and post-test pressure measurements (in kPa) obtained using the T & T Medilogic Medizintechnic system, for both the control and experimental groups. The control group exhibited an increase in pressure from 45 kPa at pre-test to 55 kPa at post-test, corresponding to a change of +11 kPa. The experimental group demonstrated a slightly greater increase, from 44 kPa to 56 kPa, reflecting a +12 kPa change.

Table 1 The values of BMI in pre and post-tests for both groups

Group	Pre-test (BMI in kg/m^2)	Post-test (BMI in kg/m^2)	Change	t-value	d-Cohen's	p-value
Control	18.5	18.6	0.1	0.72	0.34	0.48
Experimental	18.2	17.9	-0.3	2.45	0.56	0.018

*Significant differences, p< .05.

Note Nuriu & Bendo (2025).

Table 2 The values of pressure measured by T & T medilogic medizintechnic

Group	Pre-test (Pressure in kPa)	Post-test (Pressure in kPa)	Change	t-value	d-Cohen's	p-value
Control	45	55	11	3.21	0.48	0.004
Experimental	44	56	12	3.87	0.57	0.001

*Significant differences, p< .05.

Note Nuriu & Bendo (2025).

A paired t-test (or Wilcoxon signed-rank test for non-normal data) was applied to assess the statistical significance of these changes. For the control group, the increase was statistically significant (t = 3.21, p = 0.004, Cohen's d = 0.48), while for the experimental group, the enhancement was also significant (t = 3.87, p = 0.001, Cohen's d = 0.57), indicating a moderate effect size and a meaningful impact of the intervention on pressure distribution. These results suggest that participation in structured physical activity contributed to improvements in parameters associated with gait and postural control.

Table 3 presents the pre- and post-test values of biomechanical variables, including walking speed (m/s) and step symmetry (%), measured using the BTS G-sensor (G-WALK) system, for both control and experimental groups. In terms of walking speed, the control group showed a minimal increase from 1.00 m/s at pre-test to 1.01 m/s post-test, corresponding to a change of +0.01 m/s. Conversely, the experimental group exhibited a more substantial improvement, increasing from 1.02 m/s to 1.15 m/s, representing a change of +0.13 m/s. Statistical analysis using a paired t-test indicated that the change in walking speed in the experimental group was statistically significant (t = 4.12, p < 0.001, Cohen's d = 0.68), whereas the change in the control group was not significant (t = 0.52, p = 0.61, Cohen's d = 0.08), highlighting the moderate practical effect of the intervention on gait velocity.

Table 3 The biomechanical variables measured by BTS G-sensor (G-WALK) in experimental and control group.

Parameter	Group	Pre-test	Post-test	Change	t-test	d-Cohen's	p-value
Walking speed (in m/s)	Control	1	1.01	0.01	0.52	0.08	0.61
	Experimental	1.02	1.15	0.13	4.12	0.68	0
Step symmetry	Control	95	96	1	0.87	0.1	0.39
(in %)	Experimental	94	98	4	3.98	0.65	0

*Significant differences, p< .05.

Note Nuriu & Bendo (2025).

Regarding step symmetry, the control group improved marginally from 95% to 96% (+1%), while the experimental group increased from 94% to 98% (+4%). The paired t-test results confirmed that the improvement in the experimental group was statistically significant (t = 3.98, p < 0.001, Cohen's d = 0.65), whereas the control group's change did not reach significance (t = 0.87, p = 0.39, Cohen's d = 0.10). These findings indicate that structured physical activity effectively enhances both gait symmetry and speed in children and adolescents.

Table 4 presents the postural sway measurements, expressed as the Stability Index (SI in cm), for both the control and experimental groups, obtained using the Leonardo GRF Mechanography system. The control group exhibited a marginal increase in postural sway, with SI rising from 2.4 cm at pre-test to 2.5 cm at post-test, reflecting a change of +0.1 cm. In contrast, the experimental group demonstrated a significant improvement, with SI decreasing from 2.6 cm pre-intervention to 1.9 cm post-intervention, corresponding to a -0.7 cm change.

Table 4 The values of postural sway in pre and post-tests measured in Leonardo GRF Mechanography

Group	Pre-test (SI in cm)	Post-test	(SI in cm)	Change	t-value	d-Cohen's	p-value
Control	2.4	2.5		0.1	0.56	0.07	0.58
Experimental	2.6	1.9		-0.7	5.12	0.75	0

*Significant differences, p< .05.

Note Nuriu & Bendo (2025).

Statistical analysis using a paired t-test revealed that the decrease in SI for the experimental group was statistically significant (t = 5.12, p < 0.001, Cohen's d = 0.75), indicating a large effect size and a substantial improvement in postural stability. Conversely, the change observed in the control group was not significant (t = 0.56, p = 0.58, Cohen's d = 0.07), suggesting that routine activities without structured physical exercise did not meaningfully affect postural sway. These results indicate that the structured physical activity intervention effectively reduced postural sway, enhancing balance and postural control in children and adolescents.

Table 5 presents the pre- and post-test posture variables, specifically shoulder slope and pelvic tilt (in degrees), measured using the Posture Screen Mobile application for both control and experimental groups. For shoulder slope, the control group exhibited a slight increase from 5.2° at pre-test to 5.3° at post-test, corresponding to a change of +0.1°.

Table 5 The posture variables measured by Posture screen mobile in both experimental and control group

Parameter	Group	Pre-test	Post-test	Change	t-test	d-Cohen's	p-value
Shoulder slope (in degree)	Control	5.2	5.3	0.1	0.32	0.05	0.75
	Experimental	5	4.2	-0.8	4.28	0.63	0
Pevic tilt	Control	7.1	7	-0.1	0.47	0.06	0.65
(in degree)	Experimental	7.2	5.8	-1.4	5.53	0.79	0

*Significant differences, p< .05.

Note Nuriu & Bendo (2025).

The experimental group demonstrated a substantial reduction, decreasing from 5.0° to 4.2°, reflecting a change of -0.8°. Statistical analysis using a paired t-test confirmed that the improvement in the experimental group was statistically significant (t = 4.28, p < 0.001, Cohen's d = 0.63), while the change in the control group was not significant (t = 0.32, p = 0.75, Cohen's d = 0.05). For pelvic tilt, the control group showed a negligible decrease from 7.1° to 7.0° (-0.1°), whereas the experimental group exhibited a pronounced improvement from 7.2° to 5.8° (-1.4°). The paired t-test results indicated that the reduction in pelvic tilt in the experimental group was statistically significant (t = 5.43, p < 0.001, Cohen's d = 0.79), with a large effect size, whereas the control group's change was not significant (t = 0.47, p = 0.65, Cohen's d = 0.06). These results demonstrate that the structured physical activity intervention significantly improved both shoulder alignment and pelvic positioning in children and adolescents.

Discussion

The findings of this study underscore the significant influence of structured physical activity interventions on various aspects of body composition, gait, and postural development in children and adolescents. Across the analyzed parameters: body mass index (BMI), plantar pressure, walking speed, postural sway, and postural alignment the experimental group consistently demonstrated superior outcomes compared to the control group, confirming the multifaceted benefits of physical exercise in promoting musculoskeletal health and functional performance. The data presented in Table 1 revealed a notable reduction in BMI among participants in the experimental group (-0.3 kg/m^2), while the control group exhibited a marginal increase (+0.1 kg/m^2). This outcome signifies the positive role of structured exercise in managing body composition among school-aged children. The effect size (Cohen's *d* = 0.56) indicated a moderate yet practically meaningful improvement, suggesting that even relatively short-term physical activity interventions can yield beneficial physiological changes.[22] Such a reduction in BMI is not only reflective of improved body composition but may also contribute to enhanced musculoskeletal function. Previous studies have demonstrated that reduced body mass and more balanced weight distribution positively affect posture, muscle strength, and gait efficiency.[4,11] Conversely, the control group's slight BMI increase highlights concerns about the negative impact of sedentary behavior and insufficient physical engagement on postural development and gait formation.

The improvements in the experimental group can be attributed to the integration of aerobic, strength, and balance exercises within the structured intervention, which collectively enhance energy expenditure and functional musculoskeletal adaptation.[5] Additionally, such programs may foster proprioceptive awareness and core stabilization mechanisms that play a vital role in postural alignment and overall physical stability.[24] Consequently, structured physical activity during primary education emerges as a key strategy for supporting both healthy BMI management and proper motor development. Table 2 findings indicated improvements in plantar pressure measurements for both groups, though the experimental group achieved slightly greater gains (+12 kPa) compared to the control group (+11 kPa). The moderate effect size (*d* = 0.57) confirmed the practical relevance of these enhancements, implying that structured exercise interventions effectively improve musculoskeletal function and gait dynamics.[21,24]

Plantar pressure data obtained through the T & T Medilogic Medizintechnic system provided meaningful insights into balance and gait mechanics. While natural developmental progression may account for some improvement in both groups, the additional progress observed in the experimental group indicates the additive benefits of targeted physical exercise focusing on coordination, balance, and lower-limb strength.[17] The superior outcomes in the experimental group support the hypothesis that structured activity enhances neuromuscular coordination and postural control, leading to more efficient gait patterns. From an educational standpoint, these results highlight the importance of embedding physical activity into school curricula. Structured movement programs not only foster healthier posture and gait but also reduce the risk of future musculoskeletal complications.[22] Future research should aim to examine the longitudinal sustainability of these effects and determine the optimal exercise types, frequency, and intensity for maximizing musculoskeletal development.

The findings in Table 3 further reinforce the positive impact of structured physical activity on gait performance. The experimental group exhibited significant improvements in both walking speed (+0.13 m/s) and step symmetry (+4%), compared to minimal changes in the control group (+0.01 m/s and +1%, respectively). These outcomes, supported by moderate effect sizes (*d* = 0.68 and 0.65), demonstrate that structured interventions lead to meaningful enhancements in locomotor function and gait biomechanics.[17,21]

Walking speed serves as a key indicator of functional mobility and lower-limb efficiency. The observed improvement in the experimental group suggests increased muscular strength, improved neuromuscular coordination, and superior balance control. Similarly, greater step symmetry indicates better bilateral coordination and stability, outcomes likely derived from exercises targeting core strength and proprioception. The negligible changes in the control group emphasize the insufficiency of unstructured school activity in driving biomechanical adaptation. Targeted therapies informed by gait analysis enhance children's walking patterns, yielding significant improvements in endurance and gait speed, with gait training identified as particularly effective for increasing gait speed.[25] These results align with prior findings linking consistent physical activity to improvements in gait performance, coordination, and musculoskeletal resilience in youth (Janssen & LeBlanc, 2010). On a broader scale, these enhancements may translate into reduced injury risk, improved physical literacy, and more efficient motor control. Hence, incorporating structured exercise into educational frameworks is essential for supporting children's physical and cognitive development.

Table 4 demonstrated a substantial reduction in postural sway in the experimental group (-0.7 cm), contrasted with negligible change in the control group (+0.1 cm). This large effect size ($d = 0.75$) suggests significant improvement in postural control and neuromuscular coordination (García-Soidán et al., 2020). Postural sway serves as a key indicator of balance and stability, and its reduction signifies enhanced proprioceptive control and core muscle function.

The intervention's emphasis on core strengthening, balance, and lower-limb exercises likely underpinned these improvements.[5] The absence of change in the control group further supports the necessity of structured, targeted exercise to achieve measurable gains in stability. Previous evidence also corroborates that physical activity interventions enhance postural metrics in children, promoting efficient gait and reducing the likelihood of musculoskeletal problems.[11] Integrating such structured physical programs in both educational and clinical contexts could thus foster balance, coordination, and long-term physical health. Continued research should explore the persistence of postural benefits and determine the optimal dosage and content of such programs to ensure sustained musculoskeletal improvements.

Table 5 presented clear evidence that structured physical activity positively affects postural alignment. The experimental group demonstrated notable reductions in shoulder slope (-0.8°) and pelvic tilt (-1.4°), with moderate to large effect sizes ($d = 0.63$ and 0.79, respectively). These findings contrast sharply with the negligible changes in the control group, emphasizing that physical activity promotes improved upper and lower body alignment.[4]

Improved shoulder slope implies enhanced upper-body symmetry and coordination, while reduced pelvic tilt indicates healthier lumbopelvic alignment—both crucial for efficient gait mechanics and musculoskeletal balance.[5,11] Furthermore, the observed associations between age, body mass, and various postural angles (e.g., pelvis alignment, Q-angle, knee and ankle alignment) suggest that physical activity may mitigate age-related deviations in posture, independent of sedentary behavior. From an educational and preventive health perspective, these findings support the integration of the structured exercise components into school programs to correct improper posture, improve biomechanical efficiency, and minimize the risk of postural disorders later in life. Enhanced postural alignment may further contribute to better gait performance, functional mobility, and overall child development.

Conclusion

This study presents strong evidence that structured physical activity programs significantly improve gait, posture, and musculoskeletal function in primary school-aged children and adolescents. Utilizing various biomechanical and postural assessment tools, it demonstrates improvements in walking speed, step symmetry, and postural stability linked to moderate-intensity exercise. The findings underscore the importance of physical activity for overall health and motor skill development during formative years, suggesting that structured physical education can effectively reduce postural dysfunction risks and foster efficient gait patterns. The study promotes evidence-based interventions focused on balance, coordination, and strength to enhance youth functional development. Ultimately, it calls for the implementation of programs to raise physical activity levels in young people, while highlighting the need for future research to explore long-term benefits and the effects of different exercise methods on cognitive and psychosocial outcomes.

Limitations of the study

Despite promising results, the study has limitations such as a small sample size focused on children and adolescents from a single area, and a short intervention duration of 12 weeks, which restricts long-term benefit assessments. Measurement errors from various validated instruments may have affected accuracy in outcomes related to biomechanics and posture. Additionally, unmeasured factors like dietary habits and psychosocial elements could distort findings. The report emphasizes the need for structured physical activity in primary schools, highlighting its positive effects on neuromuscular development and functional movement. It suggests curriculum improvements incorporating balance, coordination, strength, and stability training to enhance physical literacy and health among youth, potentially reducing the risk of postural and gait-related issues in the future.

Future directions

In this study we suggest examining the long-term sustainability of increased gait, postural, and overall musculoskeletal strength and functional benefits across months or years. Extensive sampling, a broader regional and socio-economic profile, and a more heterogeneous sample could contribute in enhancing generalizability of findings. More controlled experimentation is required to find out what sorts, intensities, and rate of physical exercise would yield maximum effects on different performance measures such as cognitive performance, emotional health, psychological wellbeing and academic performance. Moreover, the use of higher quality biomechanical analysis methods and wearable technologies may provide a deeper understanding of movement patterns and postural adjustments in youth development.

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Conflict of interest

The authors declare no conflict of interest.

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References

1. He H, Yang Y, Sun J, et al. Effects of school-based physical activity on academic achievement in children and adolescents: a systematic review and meta-analysis. *Frontiers in public health*. 2025;13:1651883.
2. Grobler B, Kramer M. The Acute effects of schoolbag loading on posture and gait mechanics in 10- to 13-year-old children: a cohort from the north west province. *Children*. 2023;10(9):1497.
3. Araújo CL, Moreira A, Carvalho GS. Postural education programmes with school children: a scoping review. *Sustainability*. 2023;15(13):10422.
4. García-Soidán JL, García-Liñeira J, Leirós-Rodríguez R, et al. Physical activity practice and optimal development of postural control in school children: are they related?. *Journal of clinical medicine*. 2020;*9*(9):2919.
5. Michaela S, Mandzáková M, Martina M. Effect of an exercise program on the body posture of young school-age children. *Journal of Physical Education and Sport.* 2024;24(3):747–753.
6. Goyal D. Impact of a physical activity program on body posture in young elementary school students. International Journal of Physiology, Health and Physical Education. 2023;5(1):19–20.
7. de Assis SJC, Sanchis GJB, de Souza CG, et al. Influence of physical activity and postural habits in schoolchildren with scoliosis. *Archives of public health Archives belges de sante publique*. 2021;*79*(1):63.
8. Martínez-Romero MT, De Ste Croix M, Sainz de Baranda P. Postural fitness protocol in children and adolescents: descriptive values from the ISQUIOS program. *Children*. 2025;12(9):1253.
9. Mohseni Bandpei MA, Osqueizadeh R, Goudarzi H, et al. Predictors of static postural loading in primary-school-aged children: Comparing elastic net and multiple regression methods. *Children.* 2025;12(6):744.
10. Salsali M, Sheikhhoseini R, Sayyadi P, et al. Association between physical activity and body posture: A systematic review and meta-analysis. *BMC Public Health.* 2023;23:1670.
11. Rogge AK, Hamacher D, Cappagli G, et al. Balance, gait, and navigation performance are related to physical exercise in blind and visually impaired children and adolescents. *Experimental Brain Research.* 2021;*239*(4):1111–1123.
12. Lythgo N, Wilson C, Galea M. Basic gait and symmetry measures for primary school-aged children and young adults whilst walking barefoot and with shoes. *Gait & posture*. 2009;*30*(4):502–506.
13. Capili B, Anastasi JK. An introduction to types of quasi-experimental designs. *The American journal of nursing*. 2024;*124*(11):50–52.
14. World health organization. Guidelines on physical activity and sedentary behaviour. WHO Press. 2020.
15. Fricke O, Weidler J, Tutlewski B, et al. Mechanography—A new device for the assessment of muscle function in pediatrics. *Pediatric Research. 2006;*59(1):46–49.
16. Cousins SD, Morrison SC, Drechsler WI. The reliability of plantar pressure assessment during barefoot level walking in children aged 7-11 years. *Journal of foot and ankle research*. 2012;*5*(1):8.
17. Muro-de-la-Herran A, Garcia-Zapirain B, Mendez-Zorrilla A. Gait analysis methods: an overview of wearable and non-wearable systems, highlighting clinical applications. *Sensors*. 2014;14(2):3362-3394.
18. Ghasemi A, Zahediasl S. Normality tests for statistical analysis: a guide for non-statisticians. *International journal of endocrinology and metabolism*. 2012;10(2):486–489.
19. Chaparro-Rico BDM, Cafolla D. Test-retest, inter-rater and intra-rater reliability for spatiotemporal gait parameters using sane (an easy gait analysis system) as measuring instrument. *Applied Sciences*. 2020;10(17):5781.
20. Lin J, Wang Y, Sha J, et al. Clinical reliability and validity of a video-based markerless gait evaluation method. *Frontiers in pediatrics*. 2023;11:1331176.
21. Cohen J. Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers. 1988.
22. Janssen I, LeBlanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity.* 2020;7:40.
23. Carvalho BKG, Ribeiro AP, João SMA. Correlation between physical activity and anthropometric measurements among children and adolescents. *Journal of manipulative and physiological therapeutics*. 2024;47(1-4):45–57.
24. ElMoslemany AG, Abdelaziz KS, Botla AM, et al. Impact of core stability exercises combined with proprioceptive training on postural stability in obese adult females: A randomized controlled trial. International Journal of Kinesiology and Sports Science. 2025;13(2):1–11.
25. Nuriu D, Spahiu E, Bendo A. The gait analysis at children aged 6-18 years old - a comprehensive review. *Edelweiss Applied Science and Technology*. 2024;*8*(6):8108–8116.