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Original Article

An SEM-Based Evaluation of the Effect of Structured Locomotor Skill Training on Physical Activity Levels and Motor Development in Primary-School Children

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Abstract

Introduction: Research indicates that structured interventions focusing on locomotor skills can improve motor competence and encourage active lifestyles. However, the specific mechanisms that connect the acquisition of these skills to broader aspects of motor development have not been thoroughly investigated.
Objective: This research sought to assess the impact of a structured locomotor skill training program on the physical activity (PA) levels and motor development of primary school children.
Methods: A quasi-experimental design was utilized involving 120 children aged 8 to 10, who were randomly divided into intervention (n=60) and control (n=60) groups. The intervention comprised a structured locomotor skill program conducted over 12 weeks during physical education classes. Standard tools were used for measuring research variables. Structural equation modeling (SEM) analyses were performed for data analysis.
Results: Children participating in the intervention group exhibited significant enhancements in locomotor skill proficiency (ΔTGMD-3=+6.1, p<.001) and overall motor development (ΔBOT-2=+5.4, p<.001) when compared to the control group. SEM indicated a significant positive relationship between locomotor skill proficiency and PA (β=0.58, p<.001), along with a partial mediation effect of PA on the connection between locomotor skills and overall motor development (indirect β=0.35, 95% CI [0.21, 0.51], p<.001).
Conclusion: Structured locomotor-skill training can be effectively integrated into primary-school PE to enhance children's motor development and PA levels.

Keywords: Motor Skills, Child, Exercise, Physical Fitness, Motor Development

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1. Introduction

Physical activity (PA) during childhood is crucial for a variety of health, developmental, and psychosocial outcomes (1,2). Adequate levels of PA are linked to favorable body composition, enhanced cardiorespiratory and muscular fitness, improved cognitive abilities, and overall positive psychosocial health in children (3,4). For instance, those who engage in higher amounts of moderate-to-vigorous PA (MVPA) often demonstrate superior motor skills and fitness levels (5). Conversely, a lack of PA, coupled with prolonged sedentary behavior and limited movement opportunities, can lead to poor motor skills, a heightened risk of overweight and obesity, and decreased involvement in physical activities (6). Therefore, fostering PA from an early age is essential and should be prioritized in public health initiatives.

The concept of fundamental motor skills (FMS) - including running, jumping, hopping, skipping, throwing, and catching - has become a crucial element in understanding children's motor development and PA behaviors (7). FMS are often regarded as the essential components that pave the way for more advanced movement tasks, participation in sports, and overall active lifestyles (8,9). Research indicates a positive correlation between FMS proficiency and increased levels of PA, as well as greater confidence and motor competence as children grow (10,11). For example, a systematic review conducted by Jones, Innerd, Giles, and Azevedo revealed a modest yet statistically significant relationship between FMS and both total PA and MVPA in children aged 3 to 6 years ($r \approx 0.20$), suggesting that children who excel in FMS are likely to be more physically active (12). However, the nature of the relationship - specifically its directionality and causality - remains uncertain.

Research indicates that interventions designed to enhance FMS proficiency can lead to improvements in motor competence and, in some instances, increased PA (13,14). For instance, a meta-analysis conducted by Yang et al. revealed that PA programs significantly enhanced children's abilities in running, horizontal jumping, kicking, and catching when the interventions were shorter than 12 weeks and included sessions lasting at least 90 minutes (15). Additionally, systematic

reviews focusing on school-aged children have shown that FMS interventions not only improve movement skills but may also positively influence PA behaviors and overall motor development (16).

Despite the increasing body of evidence, significant gaps persist in the existing literature. Primarily, while there is an abundance of cross-sectional studies, there is a notable scarcity of longitudinal and intervention research employing robust structural modeling techniques, such as structural equation modeling (SEM), to investigate the connections between FMS training, PA levels, and broader motor development outcomes. Additionally, much of the current research is concentrated on preschoolers or very young children, with fewer studies focusing on older primary school children, particularly those aged 8 to 11 years, to assess how structured locomotor skill training specifically affects PA behaviors and subsequent motor development (17,18). Furthermore, many investigations treat improvements in FMS and increases in PA as distinct outcomes, rather than exploring a mediation model in which structured locomotor skills training enhances FMS proficiency, which in turn influences PA levels and motor development outcomes (8,12,19). Lastly, the complex interactions among intervention effects, FMS proficiency, PA behavior, and motor development over time remain insufficiently examined, particularly in school-based settings where structured programs could be implemented.

The theoretical framework for this study is grounded in motor development and physical competence theories, particularly the model by Stodden et al. (2008). This model suggests a reciprocal relationship between motor competence, including FMS, and PA throughout childhood, with perceived competence, fitness, and motivation acting as mediators (12,20,21). In early childhood, PA is thought to enhance motor competence, while in later childhood, improved motor skills may promote increased PA (20). Although some research supports these connections, empirical investigations utilizing SEM in intervention contexts remain limited. Furthermore, structured locomotor skill training, which emphasizes movement patterns like running, hopping, and jumping, is expected to enhance FMS proficiency (22-24). This improvement may lower barriers to movement, facilitating greater engagement in PA and ultimately fostering better motor development. Thus, structured training can be viewed as a catalyst that initiates a sequence of beneficial outcomes: enhanced FMS proficiency leads to increased PA, which in turn supports improved motor development.

This study aims to assess the impact of a structured locomotor skill training program on the PA levels and motor development of children, utilizing SEM to explore both direct and indirect effects. Our focus is on primary school children, specifically those aged 8 to 10 years, who will participate in a school-based intervention over a specified timeframe. The objectives of this research are threefold: first, to evaluate whether the structured training enhances locomotor skill proficiency, a key aspect of FMS; second, to investigate the relationship between improved locomotor skills and increased PA levels, including MVPA and total PA; and third, to determine if PA serves as a mediator in the connection between locomotor skill proficiency and motor development outcomes, such as overall motor competence. The hypotheses of this study posit that the training program will significantly enhance locomotor skill proficiency compared to a control group, that higher proficiency will correlate with increased PA levels, that elevated PA will relate to improved motor development outcomes, and that PA will mediate the relationship between locomotor skill proficiency and motor development.

The importance of this study is rooted in its ability to enhance school-based physical education practices and intervention strategies by elucidating not only the effectiveness of locomotor skill training but also the mechanisms through which it operates, particularly in relation to increased PA and specific demographic groups. The application of SEM offers a robust analytical approach to evaluate proposed pathways, moving beyond mere pre- and post-intervention comparisons (25). In light of the increasing rates of sedentary behavior, motor skill deficiencies, and diminishing PA levels among children worldwide (1,3), identifying effective intervention strategies is both timely and crucial. Additionally, by concentrating on primary school children rather than solely preschoolers, this research will deepen our understanding of motor development during a pivotal stage when children's movement patterns and skills become more established, potentially influencing their PA trajectories into adolescence and adulthood.

This paper presents an evaluation of a structured locomotor skill training program using SEM within a school environment. The objective is to clarify how enhancements in locomotor skills can contribute to increased PA and motor development in primary school children. The following sections will outline the research methodology, present the findings, and discuss the implications of the study.

2. Methods

2.1. Research Design

This research employed a quasi-experimental pretest–posttest control group design to assess the impact of a structured locomotor skill training program on children's levels of PA and motor development. Additionally, SEM was utilized to explore both direct and indirect relationships between locomotor skill proficiency, PA, and motor development outcomes. This methodological approach facilitates causal inferences regarding the intervention while also enabling a model-based analysis of the mediational pathways involved.

2.2. Participants

Participants in this study were children aged 8 to 10 years, enrolled in Grades 3 to 5 at two public elementary schools. The schools were selected through stratified random sampling based on similar socioeconomic and demographic characteristics, with one designated as the intervention group and the other as the control group. A total of 120 children participated, with 60 in each group. Inclusion criteria required participants to be within the specified age range, free from physical or neurological disabilities, have parental consent and child assent, and maintain regular attendance in physical education classes. Children with medical restrictions against MVPA were excluded from the study. A power analysis conducted using GPower 3.1 (26) determined that a minimum of

98 participants was necessary to identify significant effects, confirming that the final sample size of 120 was adequate for the research objectives.

2.3. Intervention: Structured Locomotor Skill Training Program

The structured locomotor skill training program was designed in accordance with the motor development model (27) and builds on previous school-based interventions focused on FMS (16). Spanning 12 weeks, the program consisted of two 45-minute sessions each week, conducted in a school gymnasium or playground, and led by a certified physical education teacher trained by the research team. Each session concentrated on developing various locomotor skills, including running, hopping, skipping, galloping, jumping, and leaping, through progressively challenging and game-oriented drills. The activities were intentionally crafted to prioritize movement diversity, rhythm, and coordination over competitive elements. In contrast, the control group adhered to the standard physical education curriculum without any specialized locomotor training. To ensure program fidelity, weekly observations were conducted using a checklist, with a compliance target of 90% or higher across all sessions.

2.4. Measurements

To ensure validity and reliability, standardized and widely used instruments were employed for all constructs.

The Test of Gross Motor Development–Third Edition (TGMD-3) was used for measuring locomotor skills (28). It is a widely recognized standardized assessment tool designed to evaluate FMS in children aged 3 to 10 years. This test comprises two main subtests: locomotor skills, which include running, galloping, hopping, skipping, horizontal jumping, and sliding, and ball skills, which encompass throwing, catching, kicking, and striking. Each motor skill is assessed based on qualitative performance criteria over two trials, and for the purposes of this study, only the locomotor subscale was utilized to gauge proficiency in locomotor skills.

The ActiGraph GT3X+ Accelerometer was used for measuring PA. It serves as an objective instrument for measuring PA levels, capturing data on intensity, frequency, and duration. In this study, children wore the accelerometer on their right hip for a continuous period of seven days, excluding water activities and sleep, with data recorded in 15-second intervals. Non-wear time was identified as 60 minutes of consecutive zero counts, and a valid dataset was defined as having at least 10 hours of wear per day over a minimum of four days, including one weekend day. PA intensity was categorized using the thresholds established by Evenson et al. (29), with MVPA defined as 2296 counts per minute or higher, ultimately yielding the average daily minutes of MVPA.

The Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) - Short Form was used for measuring motor development (30). It is an assessment tool that evaluates both fine and gross motor skills in children and adolescents aged 4 to 21 years (Bruininks & Bruininks, 2005). This test measures various domains, including bilateral coordination, balance, running speed and agility, and strength, with standard scores serving as indicators of overall motor development.

Covariates for this study included age and sex, which were obtained from school records. Additionally, Body Mass Index (BMI) was calculated using measured height and weight in accordance with World Health Organization standards, expressed as z-scores adjusted for age and sex. Baseline PA levels were also considered in the analysis.

2.5. Procedure

Following the essential approval from the Education Department, school administrators, teachers, and parents were informed about the study's objectives and methodologies. Prior to participation, informed consent was obtained from parents, along with assent from the children involved. The research was conducted in three distinct phases: the pretest phase in Week 1 involved baseline assessments of FMS, PA levels, motor development, and anthropometric measurements for both groups. During the intervention phase from Weeks 2 to 13, the intervention group engaged in structured locomotor skill training, while the control group continued with the standard physical education program. In Week 14, the posttest phase was conducted, repeating the initial assessments, with data collection carried out by blinded assessors. All evaluations took place during school hours in a quiet gymnasium or classroom setting, and the inter-rater reliability for FMS and BOT-2 scoring was notably high, exceeding an intraclass correlation coefficient (ICC) of 0.92.

2.6. Statistical Analysis

Data analysis was performed utilizing IBM SPSS Statistics 29 and AMOS 29. Initial assessments involved evaluating normality, identifying outliers, and addressing missing data through full information maximum likelihood. Descriptive statistics were calculated, including means, standard deviations, and intercorrelations among the variables. A confirmatory factor analysis (CFA) was conducted to evaluate the measurement model's adequacy for latent constructs such as locomotor skill proficiency, PA, and motor development, with reliability and validity determined by composite reliability (CR>0.70), average variance extracted (AVE>0.50), and the Fornell–Larcker criterion for discriminant validity. The structural model tested the proposed relationships, specifically the pathways from locomotor skill proficiency to PA and subsequently to motor development, with both direct and indirect effects analyzed through bootstrapping (5000 samples, 95% CI). Model fit indices were assessed, with acceptable thresholds set at $\chi^2/df<3.0$, CFI≥0.90, TLI≥0.90, RMSEA≤0.08, and SRMR≤0.08. Finally, standardized path coefficients (β) were evaluated for significance, with p-values less than 0.05 deemed statistically significant.

3. Results

3.1. Participant Demographics

The final sample included 120 children, with 60 in the intervention group and 60 in the control group. Demographic details are outlined in Table 1. At baseline, there were no significant differences between the two groups regarding age, sex distribution, or BMI.

Table 1. Demographic Characteristics of Participants (n=120).

Characteristic	Intervention (n=60)	Control (n=60)	Total (N=120)
Age, years (M ± SD)	9.2 ± 0.7	9.1 ± 0.6	9.15 ± 0.65
Sex, n (%)			
Male	32 (53%)	31 (52%)	63 (53%)
Female	28 (47%)	29 (48%)	57 (47%)
BMI, kg/m² (M ± SD)	18.7 ± 2.1	18.9 ± 2.3	18.8 ± 2.2

3.2. Descriptive Statistics

Table 2 presents a summary of the mean scores and standard deviations for the key study variables before and after the intervention. The findings indicate that baseline assessments of locomotor skill proficiency, PA, and motor development scores showed no significant disparities (p>.05). Additionally, the intervention group experienced significant enhancements in locomotor skill proficiency, PA levels, and overall motor development when compared to the control group. Additionally, the effect sizes associated with these intervention-related improvements were found to be moderate to large, with Cohen's d values exceeding 0.60.

Table 2. Descriptive Statistics of Key Variables at Pretest and Post-test.

Variable	Group	Pre-test (M ± SD)	Post-test (M ± SD)
Locomotor Skill (TGMD-3)	Intervention	22.5 ± 3.1	28.7 ± 3.5
	Control	22.8 ± 3.0	23.1 ± 3.2
Physical Activity (MVPA, min/day)	Intervention	42.3 ± 8.7	57.6 ± 9.2
	Control	41.9 ± 9.0	43.2 ± 8.5
Motor Development (BOT-2)	Intervention	48.5 ± 4.9	55.2 ± 5.3
	Control	48.2 ± 5.1	48.7 ± 5.0

3.3. Correlations Between Study Variables

Pearson correlations were analyzed to explore the relationships among locomotor skill proficiency, PA, and motor development, as presented in Table 3. The findings indicated a moderate correlation between locomotor skill proficiency and both PA and motor development. Notably, PA exhibited a stronger correlation with motor development, implying that it may play a significant mediating role in this context.

Table 3. Pearson Correlations Among Key Variables (n=120).

Variable	1	2	3
1. Locomotor Skill	–		
2. Physical Activity	0.56**	–	
3. Motor Development	0.49**	0.62**	–

p < .01 for all correlations.

3.4. Structural Equation Modeling Results

A CFA was conducted to evaluate the measurement model, revealing that all factor loadings were significant and exceeded 0.70, which supports strong construct validity. The CR and AVE values also met the established criteria, with CR greater than 0.80 and AVE exceeding 0.50. The structural model assessed the proposed relationships among locomotor skill, PA, and motor development. The model fit indices demonstrated a favorable fit, with χ^2/df at 1.92, CFI at 0.96, TLI at 0.95, RMSEA at 0.064 (90% CI: 0.048–0.080), and SRMR at 0.043. The analysis of indirect effects, based on 5,000 bootstrapped samples, indicated a significant pathway from locomotor skill to PA and subsequently to motor development, with a standardized coefficient of β=0.35 and a 95% confidence interval of [0.21, 0.51], p<.001. The findings supported hypotheses of the study, demonstrating that structured locomotor skill training significantly enhanced locomotor proficiency, which in turn predicted increased PA. Additionally, PA was found to significantly mediate the relationship between locomotor proficiency and motor development, while a small yet significant direct effect suggested partial mediation (Table 4 and Figure 1).

Table 4. Standardized Path Coefficients for SEM Model.

Path	β	SE	p-Value
Locomotor Skill → Physical Activity	0.58	0.08	<.001
Physical Activity → Motor Development	0.61	0.07	<.001
Locomotor Skill → Motor Development (direct)	0.18	0.09	0.045

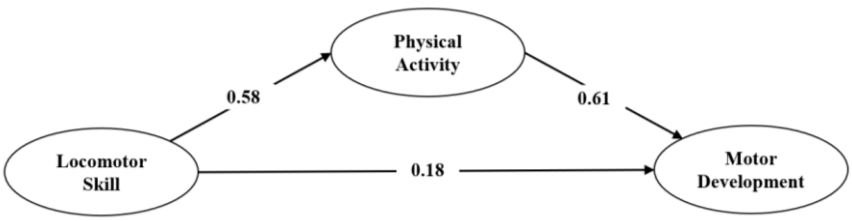

Figure 1. Research model in the form of β coefficient.

4. Discussion

This study investigated the impact of a structured locomotor skill training program on the PA levels and motor development of primary school children, utilizing SEM to analyze both direct and indirect effects. The results strongly indicate that focused locomotor interventions not only improve motor competence but also enhance engagement in physical activities and foster overall motor development. These findings align with the conceptual framework established by Stodden et al. (12,20,21), which emphasizes the interconnectedness of motor competence, PA, and health-related fitness in childhood.

The research indicated that children participating in the intervention group showed a significant enhancement in their locomotor skills compared to those in the control group. This finding aligns with previous studies that highlight the effectiveness of structured, age-appropriate FMS programs in achieving significant improvements in motor competence within brief timeframes (31,32). The increase in TGMD-3 scores implies that even a 12-week intervention can greatly boost locomotor proficiency in children aged 8 to 10. The program's structured design, featuring clear skill progression, repetitive practice, and engaging activities, likely fostered high levels of participation and effective learning (16,27). These findings underscore the importance of middle childhood as a crucial phase for motor skill development, where targeted interventions can yield enduring benefits (33). Furthermore, the positive outcomes of the intervention extend beyond mere skill acquisition; enhanced motor competence is linked to improved self-perception of motor ability, which is a significant predictor of self-efficacy and intrinsic motivation for PA among children (34). Thus, the advantages of structured locomotor skill training may encompass both physiological and psychosocial dimensions, fostering confidence, motivation, and a greater willingness to engage in diverse physical activities.

SEM analyses demonstrated a significant positive relationship between locomotor skill proficiency and levels of PA, supporting the theoretical framework established by Stodden et al. (12,20,21). This model suggests that children with greater motor competence are more inclined to engage in MVPA, as they not only feel capable but also can effectively participate in a variety of movement activities. In this study, children who underwent the intervention increased their daily MVPA by an average of 15 minutes compared to the control group, underscoring the success of locomotor-focused training in fostering active lifestyles. This finding builds on previous observational research, which identified a positive link between locomotor skills and objectively measured PA, and found that school-based motor skill interventions can enhance MVPA (12,35). The current research not only corroborates these earlier findings but also offers experimental evidence that improvements in motor skill proficiency causally led to increased PA, marking a significant advancement in the literature. The robust association identified suggests that interventions aimed at enhancing motor competence may be more effective than those that focus solely on boosting PA without skill development, aligning with recent advocacy for skill-based physical education in schools. This approach emphasizes that fostering movement competence can ultimately result in greater engagement in PA and sustained behavioral change.

A significant finding of this study is the recognition of PA as a partial mediator in the relationship between locomotor skill proficiency and overall motor development. This result emphasizes the intricate relationship between motor competence and participation in physical activities. Children who exhibit enhanced locomotor skills are more inclined to partake in physical activities, which subsequently offers them further chances to practice and apply motor skills across various areas, such as balance, coordination, and object control (12,14,36). The concept of partial mediation suggests that while locomotor skills have a direct impact on motor development, PA acts as a facilitator, promoting the application of acquired skills to more complex movements and functional tasks. This is consistent with neurodevelopmental research indicating that active engagement through practice fosters motor learning and neuromuscular adaptation, thereby enhancing overall motor competence (37). This mediation effect highlights the importance of understanding motor development as a multifaceted and interactive process, rather than merely a sequential acquisition of discrete skills. Consequently, interventions that integrate skill training with ample opportunities for diverse PA may optimize developmental outcomes and encourage the formation of lifelong PA habits.

The findings align with earlier experimental research indicating that structured FMS interventions lead to enhancements in both skill proficiency and PA levels (9,14). For example, Logan et al. (2012) demonstrated that a 10-week FMS program improved locomotor and object-control skills while also boosting children's engagement in MVPA (38). Similarly, Lubans et al. (2010) observed significant improvements in motor competence and activity levels following a school-based initiative focused on various motor skills (39). However, this study advances previous work by utilizing SEM, which facilitates the simultaneous analysis of direct and indirect relationships, thereby offering deeper insights into how locomotor skills, PA, and overall motor development are interconnected. Unlike conventional pre-post assessments, SEM allows for the evaluation of mediated effects, revealing that the association between skill proficiency and motor development is partially mediated by increased PA. This methodological innovation enhances the causal interpretation of the results and underscores the significance of mechanistic investigations in the field of motor development research.

The research outcomes present significant practical implications for educators, coaches, and policymakers. Firstly, incorporating structured locomotor skill training into physical education curricula can enhance both motor competence and PA levels, particularly in environments where children's MVPA falls short of recommended standards. Additionally, middle childhood represents a critical window for skill development; thus, early interventions aimed at improving locomotor skills can yield lasting benefits, encouraging lifelong engagement in PA and mitigating the risk of health issues associated with inactivity. Furthermore, adopting holistic approaches that combine skill mastery, play-based activities, and active participation opportunities may prove more effective than programs that concentrate solely on fitness or PA

metrics. Lastly, it is essential for educators to receive training in developmentally appropriate skill progression, motivational techniques, and motor competence assessment to ensure the effective implementation of these interventions. By prioritizing skill acquisition over mere PA, schools can cultivate competence, confidence, and enjoyment in movement, which are vital for fostering sustained participation in PA.

Structured locomotor skill training can lead to improvements through several interrelated mechanisms. First, neuromuscular adaptation occurs as repeated practice enhances motor coordination, balance, and timing, thereby increasing proficiency in various tasks. Additionally, as children become more competent, their self-efficacy rises, fostering a greater intrinsic motivation to engage in physical activities. Furthermore, structured activities often provide enjoyable and rewarding experiences, which can lead to higher participation rates and reinforce skill acquisition. Lastly, mastering foundational skills can facilitate the learning of more complex motor tasks, contributing to overall motor development. These mechanisms underscore the interconnectedness of skill acquisition, engagement in PA, and holistic development, aligning with the conceptual framework established by Stodden et al. (2008).

This study, while valuable, has several limitations that should be acknowledged. First, the sample comprised 120 children from two schools within a single urban area, which may restrict the generalizability of the findings to broader populations. To enhance external validity, it is essential to replicate the study across diverse settings and demographics. Additionally, the intervention lasted only 12 weeks, which may not adequately reflect the long-term retention of skills or sustained behavioral changes; therefore, longitudinal follow-up is crucial to evaluate the persistence of the observed effects. Furthermore, although objective measures such as accelerometers and standardized assessments were employed, the study did not account for psychosocial factors or environmental influences that could impact the results. The control group engaged in standard physical education activities without thorough monitoring of their out-of-school PA, potentially introducing uncontrolled variability into the findings. Lastly, while SEM offers valuable insights into mediated relationships, it does not allow for definitive conclusions regarding causality without the support of longitudinal or experimental mediation designs.

Future research should aim to overcome existing limitations and enhance the understanding of skill-based interventions. Longitudinal studies are essential to assess the long-term sustainability of skill improvements and increases in PA. Additionally, examining individual differences such as sex, BMI, and baseline skill levels can help identify which children are most likely to benefit from these interventions. Incorporating psychosocial and environmental factors will provide insights into the mechanisms that connect skill proficiency with PA and motor development. Furthermore, comparing various pedagogical methods - such as peer-led, technology-assisted, and family-inclusive programs - can help determine the most effective strategies for fostering engagement. Lastly, exploring cross-cultural variations is crucial, as the pathways of motor development may be influenced by differing environmental, cultural, and policy contexts.

4.1. Conclusion

This research presents compelling evidence that structured training programs focused on locomotor skills significantly enhance motor competence, boost PA levels, and foster overall motor development in primary school children. SEM analyses indicate that PA serves as a partial mediator in the relationship between locomotor skills and motor development, underscoring the interconnected and reciprocal dynamics of these elements. The implications of these findings are crucial for school-based interventions, as they highlight the importance of skill-oriented programs in promoting sustained engagement in PA and motor competence. By addressing both skill acquisition and participation in physical activities, educators and policymakers can facilitate healthier developmental pathways, establishing a foundation for physical, cognitive, and psychosocial well-being throughout childhood and adolescence.

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Footnotes

Authors' Contribution: This study was carried out solely by the corresponding author.

Conflicts of Interest

Non to declare.

Data Availability: The data that support the findings of this study are openly available upon request from the corresponding author.

Ethical Approval: The author confirms that all steps and requirements of this study comply with ethical guidelines. Participants were informed about the characteristics of the study and gave written informed consent.

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