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SCHOOL-BASED PHYSICAL ACTIVITY INTERVENTIONS: EFFECTS ON MOTOR COMPETENCE AND HEALTH-RELATED OUTCOMES IN CHILDREN – A SCOPING REVIEW [1]

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Abstract: Insufficient physical activity and declining levels of motor competence among children represent a significant public health concern. Accordingly, the aim of this scoping review was to map and synthesize the existing evidence on the effects of school-based physical activity and physical education interventions on children's motor competence, while considering their potential role within a public health framework. This scoping review was conducted in accordance with the PRISMA-ScR guidelines. A systematic literature search was carried out across four electronic databases (PubMed, Web of Science, Scopus, and Google Scholar). Two independent reviewers assessed the studies based on predefined eligibility criteria, and disagreements were resolved by consensus. A total of eighteen studies were included in the final review. The methodological quality of the included studies was assessed using the Effective Public Health Practice Project (EPHPP) quality assessment tool. The majority of the included studies demonstrated positive effects of school-based interventions on motor competence, particularly in the domains of locomotor and manipulative skills. Interventions of longer duration, as well as those characterized by structured and developmentally appropriate activities, also showed positive and more pronounced effects. School-based physical activity and physical education interventions represent an effective public health strategy for improving motor competence and supporting healthy development in childhood. Strengthening the quality and consistency of school-based movement programs may contribute to long-term health benefits and disease prevention at the population level. This scoping review identifies gaps in the existing literature and proposes directions for future research in the field of school-based motor competence interventions.

Keywords: *motor competence, physical activity, school-based intervention, health, children*

1. INTRODUCTION

The lack of physical activity among the younger population represents a significant public health issue at the global level (World Medical Association Declaration of Helsinki, 2013; Xi et al., 2020). The World Health Organization (WHO) estimates that over 80% of adolescents globally do not meet the recommended level of physical activity of

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at least 60 minutes daily of moderate to vigorous activity (World Medical Association Declaration of Helsinki, 2013). Research conducted over the past few decades has observed a drastic decline in daily physical activities alongside an increase in sedentary lifestyles among the child population (Jebeile et al., 2022; Ogden et al., 2018). This lifestyle leads to adverse health outcomes at later stages of life. Low levels of physical activity in childhood are associated with increased risk of excess weight and obesity, reduced physical fitness, poor cardiometabolic health, and adverse psychosocial outcomes (Ogden et al., 2018; Phelps et al., 2024). For this reason, the promotion of physical activity in early life is considered the foundation of disease prevention as well as health improvement within the public health approach.

Motor competence is defined as the degree of mastery of fundamental motor skills such as locomotor, manipulative, and stabilization skills (Stodden et al., 2008). It plays a key role in children's engagement in physical activity and their overall healthy development (Lopes et al., 2017). Adequate motor competence in childhood is associated with higher levels of physical activity, better physical fitness, and more positive perception of one's own physical abilities (Lopes et al., 2020). Conversely, children with low motor competence are more prone to avoiding physical activity, adopting sedentary behaviors, and developing negative health outcomes (De Meester et al., 2020). From a life course perspective, motor competence is not only a consequence of physical activity, but also its determinant in terms of long-term participation in movement, which further emphasizes its importance as an early public health target (Lorås, 2020).

Schools are considered one of the most effective and equitable settings for implementing physical activity interventions aimed at improving motor competence and children's health (Verstraete et al., 2007). As nearly all children attend school regardless of their socioeconomic status, school-based interventions have the potential to reach large and diverse populations, reduce health inequalities, and achieve health benefits at the overall population level (Yuksel et al., 2020). Physical education classes, structured physical activity programs, and extracurricular movement activities in school environment provide regular opportunities for children to practice and develop motor skills in a supervised and developmentally appropriate context (Neil-Sztramko et al., 2021). From a public health perspective, such interventions represent scalable and sustainable primary prevention strategies.

An increasing number of studies have examined the effects of school-based physical activity and physical education interventions on children's motor competence (Costa et al., 2024; Lämmle et al., 2016; Navarro-Patón et al., 2021). These interventions vary considerably in terms of content, duration, intensity, pedagogical approach, and target population. Some programs focus on increasing the frequency or quality of physical education classes, while others introduce additional structured activities, sports programs, or innovative approaches such as exergaming and interdisciplinary physical education models. In addition to motor competence, numerous studies have addressed broader health-relevant outcomes, including physical activity levels, physical fitness, sedentary behaviors, psychosocial well-being, and cognitive functioning, indicating the multidimensional impact of school-based movement interventions (Andermo et al., 2020; Pulling Kuhn et al., 2021). Despite the growing number of intervention studies, existing evidence remains fragmented due to the heterogeneity of research designs, assessment instruments, and outcome measures (Guo et al., 2024; Vernadakis et al., 2015; Ye et al., 2018). Therefore, there is a need for an integrated synthesis of the existing literature that not only summarizes the effects of school-based physical activity interventions on motor competence, but also places these findings in a broader public health context. Such a synthesis can provide valuable insights into which types of interventions are most effective, which domains of motor competence are most sensitive to change, and how improvements in motor competence can contribute to broader health outcomes in childhood.

Therefore, the aim of this scoping review is to map and synthesize the existing evidence on the effects of school-based physical activity and physical education interventions on children's motor competence and to consider their significance as a public health strategy. Specifically, this review aims to:

- Identify and map types of school-based interventions aimed at improving motor competence;
- Synthesize findings on the effects of these interventions on different domains of motor competence;
- Identify gaps in the literature and areas requiring further research attention;
- Consider implications for public health practice and policy.

2. METHOD

This study was conducted as a scoping review in accordance with the PRISMA-ScR guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews), which represent a standardized methodological framework for this type of literature review. The scoping review methodology enables

mapping of the scope and nature of available literature on school-based physical activity and physical education interventions aimed at improving motor competence in children, and identifying key concepts, knowledge gaps, and directions for future research. The implementation of these guidelines ensured a systematic and transparent approach in the process of identifying, selecting, and synthesizing relevant scientific publications (Page et al., 2021).

2.1. Search Strategy

The identification of relevant publications was carried out through a systematic search of selected electronic databases. The search strategy encompassed four scientific databases: PubMed, Web of Science, Scopus, and Google Scholar. A detailed specification of keyword combinations and search terms in English is presented in the following tabular format (Table 1).

Table 1. *Search Strategy*

Database	Search Strategy
PubMed	("Schools" OR "Physical Education and Training" OR school-based) AND ("Motor Skills" OR "Motor Activity" OR "motor competence" OR "fundamental movement skills") AND ("Exercise" OR "Physical Fitness" OR "physical activity") AND ("Child" OR "Adolescent" OR „children“ OR „adolescents“)
Web of Science	("Schools" OR school-based) AND ("Motor Skills" OR "Motor Activity" OR "motor competence") AND ("Physical Fitness" OR "physical activity") AND ("Child" OR "Adolescent")
Scopus	("Schools" OR school-based) AND ("Motor Skills" OR "Motor Activity" OR "motor competence") AND ("Physical Fitness" OR "physical activity") AND ("Child" OR "Adolescent")
Google Scholar	("Schools" OR "Physical Education and Training" OR school-based) AND ("Motor Skills" OR "Motor Activity" OR "motor competence" OR "fundamental movement skills") AND ("Exercise" OR "Physical Fitness" OR "physical activity") AND ("Child" OR "Adolescent" OR „children“ OR „adolescents“)

2.2. Inclusion Criteria

Studies were included in the review if they met the following criteria: (1) they involved preschool or primary school-aged children; (2) they examined school-based physical activity or physical education interventions conducted during regular classes or within extracurricular school programs; (3) they assessed motor competence or motor skills as a primary or secondary outcome, using standardized or validated instruments; (4) they applied an experimental, quasi-experimental, or longitudinal intervention design; and (5) they were published in peer-reviewed scientific journals in English within the defined publication period (2007-2025).

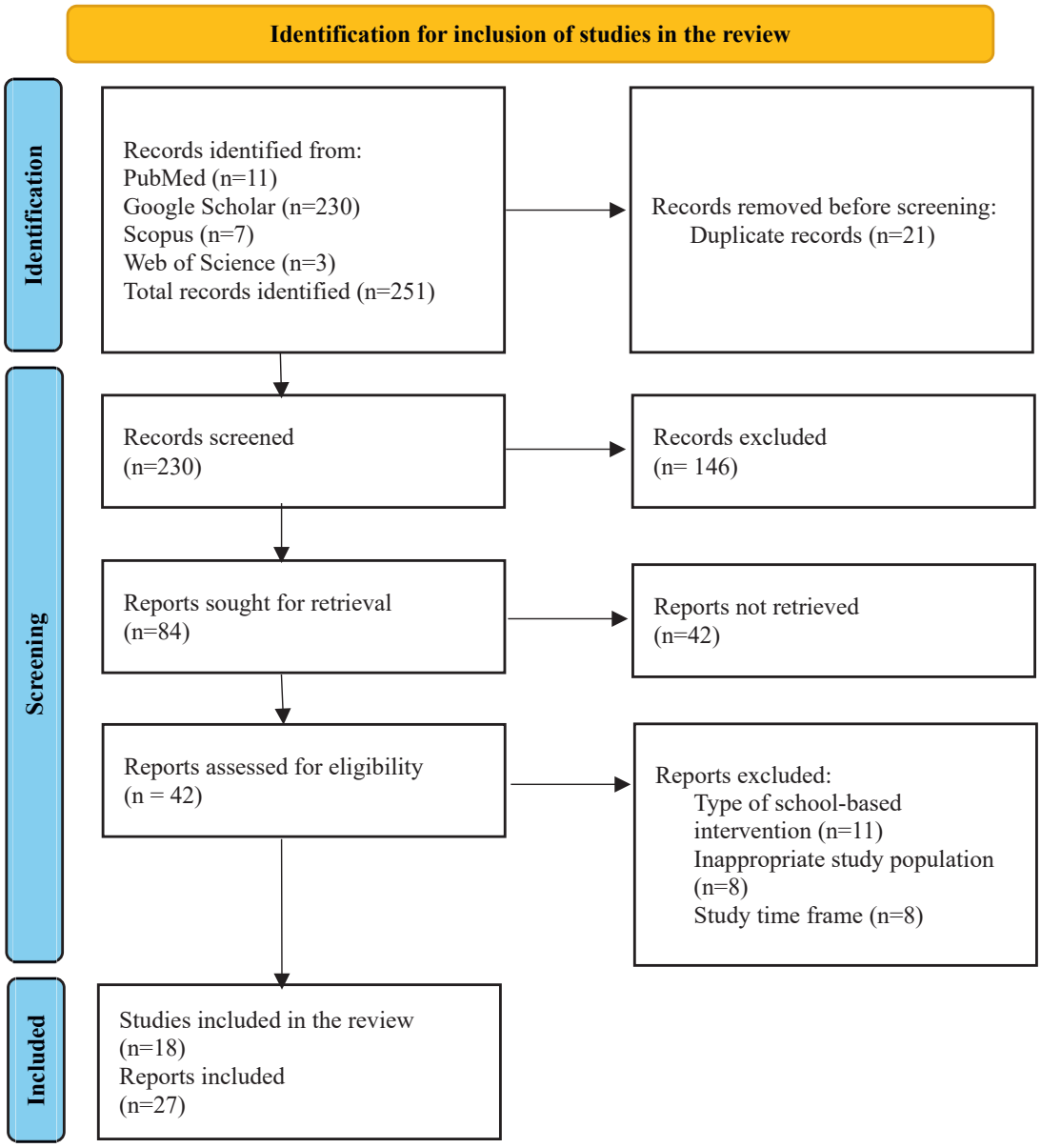
Studies were excluded if they: (1) were focused exclusively on adolescent or adult populations; (2) were conducted outside the school environment; (3) did not include an intervention component; (4) assessed exclusively physical activity levels or physical fitness without measures of motor competence; or (5) were review articles, conference abstracts, doctoral dissertations, or publications that had not undergone peer review.

2.3. Study Selection

The study selection process was conducted in accordance with the PRISMA-ScR methodology through the following phases (Diagram 1):

- Identification: Systematic search of four electronic databases.
- Screening of titles and abstracts: Two independent reviewers (SD and MD) assessed the titles and abstracts of all identified articles according to the inclusion criteria.
- Eligibility assessment: Full texts of potentially relevant studies were analyzed in detail by both reviewers to confirm fulfillment of all inclusion criteria.
- Resolution of disagreements: All disagreements between reviewers were resolved through discussion and consensus.
- Inclusion: Studies that clearly met all criteria were retained for data extraction and synthesis of findings.

Diagram 1. *PRISMA-ScR Flow diagram of the study selection process*



2.4. Data Extraction

The data from included studies were extracted using a standardized form that was pilot-tested on a sample of five studies. Two reviewers independently extracted the following data from each study:

- Study characteristics - Author and year of publication; Country and study setting; Research design; Follow-up duration/intervention duration.
- Participant characteristics - Sample size (experimental and control groups); Age of participants.
- Intervention characteristics - Type of intervention (e.g., physical education, structured programs, exergaming); Duration and frequency of intervention; Program content and structure.
- Outcome measures - Primary outcome: motor competence (instrument, domains assessed); Secondary outcomes: physical activity level, physical fitness, health parameters, psychosocial outcomes.
- Findings - Main results related to motor competence; Effects on secondary outcomes.

Disagreements in data extraction were resolved through discussion between reviewers. All extracted data were organized in tabular format (Table 3) and used for narrative synthesis of findings.

2.5. Quality Assessment of Included Studies

Although methodological quality assessment is not a mandatory component of scoping reviews according to PRISMA-ScR guidelines (Tricco et al., 2018), the quality of the included studies was assessed using the EPHPP tool (Effective Public Health Practice Project Quality Assessment Tool) for the following reasons:

- Enabling contextualization of findings and identification of methodological strengths and limitations of the existing evidence base;
- Informing the interpretation of results;
- Providing guidance for methodological improvements in future research in this area.

The EPHPP tool assesses six key domains: selection bias, study design, confounders, blinding, data collection methods, and withdrawals and dropouts. Each study was classified as strong, moderate, or weak (Table 2). Quality assessment was conducted by one reviewer (MD) and verified by another reviewer (SD). This assessment was not used to exclude studies, but solely to inform the synthesis of results and identify gaps in methodological rigor.

Table 2. *Methodological quality assessment of included studies using EPHPP tool*

Author (year)	Study design	Sample size	Selection bias	Confounders	Data collection methods	Withdrawals	Global rating
Verstraete i sar. (2007)	Cluster RCT	764	Strong	Strong	Strong	Moderate	Strong
Fotrousi i sar. (2012)	Quasi-experimental	36	Moderate	Moderate	Moderate (TGMD-2)	Strong	Moderate
Sacchetti i sar. (2014)	Cluster intervention	~500	Strong	Moderate	Strong	Moderate	Strong
Vernadakis i sar. (2015)	Quasi-experimental	66	Moderate	Moderate	Strong	Moderate	Moderate
Bremer i sar. (2015)	Pilot RCT	9	Weak	Weak	Moderate	Moderate	Weak
Senturk i sar. (2015a)	Quasi-experimental	100	Moderate	Moderate	Moderate	Moderate	Moderate
Lämmle i sar. (2016)	Longitudinal intervention	>1500	Strong	Strong	Strong	Moderate	Moderate-Strong
Lopes i sar. (2020)	Quasi-experimental	60	Moderate	Moderate	Strong	Moderate	Moderate
Lo i sar. (2017)	Cross-sectional	649.442	Moderate	Moderate	Moderate	N/A	Moderate
Ye i sar. (2018)	Quasi-experimental	261	Moderate	Moderate	Strong	Moderate	Moderate
Chen i sar. (2018)	Cross-sectional	265	Moderate	Moderate	Moderate	N/A	Moderate
Navarro-Patón i sar. (2021)	Quasi-experimental	28	Moderate	Moderate	Strong (MABC-2)	Strong	Moderate
Kliziene i sar. (2021)	Quasi-experimental	186	Moderate	Moderate	Moderate	Moderate	Moderate

Zhang i sar. (2022)	Quasi-experimental	4 clasess	Moderate	Moderate	Strong (MABC-2)	Moderate	Moderate
Guo i sar. (2024a)	RCT	88	Moderate	Moderate	Strong (MCA)	Strong	Moderate
Nicolosi i sar. (2024)	Quasi-experimental	76	Moderate	Moderate	Strong (TGMD)	Moderate	Moderate
Costa i sar. (2024)	RCT	38	Moderate	Strong	Strong (MCA)	Moderate	Strong
Rodrigues i sar. (2025)	Controlled intervention	1034	Strong	Strong	Strong (MCA)	Moderate	Strong

Legend: *RCT = Randomized Controlled Trial; TGMD = Test of Gross Motor Development; MABC-2 = Movement Assessment Battery for Children, Second Edition; MCA = Motor Competence Assessment; N/A = Not Applicable; TGMD-2 = Test of Gross Motor Development, Second Edition*

3. RESULTS

This review synthesized findings from 18 studies that examined the effects of school-based physical activity interventions on motor competence and health-relevant outcomes in children. The studies were conducted between 2007 and 2025 and encompassed different intervention designs, their duration, and diverse populations across multiple countries. Two included studies had a cross-sectional design and were used to contextualize the associations between motor competence, physical activity, and health-relevant outcomes, rather than to conclude the effects of the interventions.

3.1. Study Characteristics

The characteristics of the included studies are presented in Table 3. For each included study, relevant information was extracted and summarized, including: authors and year of publication; country where the study was conducted; study design; sample characteristics (age range and sample size); type and duration of intervention; assessment instruments used to measure motor competence; as well as main findings related to motor competence and health-relevant outcomes. Data extraction was focused on identifying patterns and consistency among studies, rather than calculating pooled effect sizes.

Table 3. *Characteristics of included studies*

Author (year)	Country	Age group	Sample size	Study design	Intervention type and duration	Motor competence assessment	Main outcomes
Verstraete et al. (2007)	Belgium	10-11 years	764	Cluster RCT	School PA program; 1 school year	Motor coordination tasks	PA levels, motor competence
Fotrousi et al. (2012)	Iran	6-7 years	36	Quasi-experimental	Structured PE program; 12 weeks	TGMD-2	Fundamental motor skills
Sacchetti et al. (2013)	Italy	8-11 years	~500	Cluster intervention	Enhanced PE curriculum, 2 years	Motor skills battery	Motor skills, fitness

Vernadakis et al. (2015)	Greece	4-6 years	66	Quasi-experimental	Exergaming-based PA; 8 weeks	Motor skills tests	Balance, coordination
Bremer et al. (2015)	Canada	4-6 years	9	Pilot RCT	Play-based PA, 6 weeks	TGMD	Motor skill acquisition
Senturk et al. (2015)	Turkey	5 years	100	Quasi-experimental	Movement education, 8 weeks	Motor skills tests	Fundamental motor skills
Lämmle et al. (2016)	Germany	6-10 years	>1500	Longitudinal	PE quality enhancement, 2 years	Motor competence battery	Motor competence
Lopes et al. (2017)	Portugal	6-10 years	60	Quasi-experimental	Structured PA sessions, 24 weeks	Motor coordination tests	Motor competence
Lo et al. (2017)	Thailand	6-11 years	649,442	Cross-sectional	---	Proxy motor indicators	PA, obesity risk
Chen et al. (2018)	SAD	11 years	265	Cross-sectional	---	Motor skills assessment	PA, fitness
Ye et al. (2018)	China	6-9 years	261	Quasi-experimental	School-based PA; 9 months	Motor competence tests	Motor competence
Navarro-Patón et al. (2021)	Spain	4-5 years	28	Quasi-experimental	Psychomotor program; 6 weeks	MABC-2	Motor competence
Kliziene et al. (2021)	Lithuania	6-9 years	186	Quasi-experimental	PE-based intervention; 8 months	Motor skills battery	Motor skills
Zhang et al. (2022)	China	6-7 years	4 classes	Quasi-experimental	PE intervention; 12 weeks	MABC-2	Motor competence
Guo et al. (2024)	China	3-5 years	88	RCT	Structured PA; 8 weeks	MCA	Motor competence
Nicolosi et al. (2024)	Italy	8-10 years	76	Quasi-experimental	PE enhancement, 12 weeks	TGMD	Motor competence
Costa et al. (2024)	Portugal	9-10 years	38	RCT	FA + PE intervention, 12 weeks	MCA	Motor competence, PA
Rodrigues et al. (2025)	Portugal	6-12 years	1034	Controlled intervention	School-based PA; 12 weeks	MCA	Motor competence, health

Legend: *PA = Physical Activity; PE = Physical Education; RCT = Randomized Controlled Trial; TGMD = Test of Gross Motor Development; MABC-2 = Movement Assessment Battery for Children, Second Edition; MCA = Motor Competence Assessment*

3.2. Effects on Motor Competence

Motor competence was the primary outcome in the majority of studies, with assessments focused on fundamental motor skills, including locomotor skills, object control skills, and stabilization skills. Various assessment instruments were used, including the Test of Gross Motor Development (TGMD and TGMD-2), the Movement Assessment Battery for Children (MABC-2), and the Motor Competence Assessment (MCA). Traditional physical education interventions showed significant improvements in motor competence. Rodrigues et al. (2025) reported significant advances in motor competence through the "Super Quinas" program, which included 1,034 children, with improvements observed across all domains of motor skills. Similarly, Lopes et al. (2017) found that structured physical education programs effectively enhance motor competence in primary school-aged children, emphasizing the importance of adequate practice opportunities and developmentally appropriate activities. Nicolosi et al. (2024) demonstrated that an interdisciplinary physical education program leads to significantly greater improvements in object control skills and locomotor skills compared to traditional exercise-based approaches. The experimental group showed large effect sizes for object control skills in both sexes, as well as significant improvements in locomotor skills, particularly among girls. These findings indicate that integrative teaching approaches that connect physical education with other curricular areas may be more effective than conventional methods. The importance of intervention type and quality was further highlighted by Guo et al. (2024), who compared structured sports games with psychomotor activities in preschool children. The results showed that structured sports games led to significantly better outcomes in the locomotor and manipulative domains compared to psychomotor activities and control conditions, with effect sizes ranging from medium to large ($d = 0.783$ to 0.998). The authors attributed these more favorable outcomes to the competitive, social, and motivating nature of structured games. Technology-based interventions also showed potential. Vernadakis et al. (2015) examined exergaming as a supplementary intervention and found moderate positive effects on fundamental motor skills when applied in combination with traditional physical education. However, Ye et al. (2018) reported mixed results for exergaming-based interventions, with significant improvements in musculoskeletal fitness and body mass index (BMI), but limited effects on cardiorespiratory fitness and object control skills compared to traditional physical education approaches. Intervention duration proved to be an important factor. Lämmle et al. (2016) showed that longer interventions (2 years) lead to sustained improvements in motor skills, with children from the intervention group maintaining significantly higher levels of motor competence compared to the control group. Similarly, Zhang et al. (2022) found that even a 12-week intervention can result in significant improvements in manual dexterity, aiming and catching, as well as overall motor competence, particularly when activities were specifically designed to target these skills. Specific populations also benefited from targeted interventions. Bremer et al. (2015) showed that children with autism spectrum disorder achieved improvements in fundamental motor skills following a targeted intervention, although the small sample size ($n = 9$) limits the generalizability of the findings. Fotrousi et al. (2012) reported improvements in children with developmental coordination disorder through compensatory movement programs, highlighting the potential of adapted physical activity programs in responding to specific developmental needs.

3.3. Effects on Physical Activity Levels

Multiple studies examined the impact of interventions on overall physical activity levels, with predominantly positive findings reported. Verstraete et al. (2007) reported a significant increase in physical activity levels, measured by accelerometry, in the intervention group compared to the control group, with children achieving considerably more moderate to vigorous physical activity (MVPA) during physical education classes, as well as throughout the entire school day. Costa et al. (2024) found that a comprehensive school intervention that included physical education classes, recess activities, and active breaks led to significant improvements in daily physical activity levels, sleep quality, aerobic fitness, and motor competence. This study highlighted the importance of multicomponent interventions that extend beyond the framework of traditional physical education classes and contribute to creating a school environment that promotes movement. However, not all studies recorded consistent increases in physical activity. Lo et al. (2017), in a large cross-sectional study that included 649,442 children, found complex relationships between participation in physical education classes and physical activity levels, indicating that physical education alone may not be sufficient to achieve recommended daily physical activity levels without additional supporting components and environmental modifications.

3.4. Effects on Health-Related Physical Fitness

Outcomes related to health-related physical fitness, including cardiorespiratory fitness, muscular strength, and flexibility, showed consistent improvements across multiple studies. Cohen et al. (2015) reported significant improvements in cardiorespiratory fitness and muscular strength following a cluster intervention that included approximately 460 children. The intervention combined structured conditioning activities with motor skill development components. Lämmle et al. (2016) demonstrated sustained improvements in physical fitness components over a two-year intervention period, with particularly pronounced advances in aerobic capacity and muscular endurance. These findings indicate that long-term interventions can lead to stable adaptations in health-related physical fitness that may contribute to long-term health benefits. Costa et al. (2024) recorded significant improvements in aerobic fitness measured by the 20-meter progressive shuttle run test, with the intervention group having considerably higher estimated VO_2max values compared to the control group after the intervention. These improvements in cardiorespiratory fitness are particularly significant given their association with reduced risk factors for cardiovascular disease and improved metabolic health.

3.5. Cognitive and Academic Outcomes

An emerging area of research concerns the links between physical activity interventions and cognitive functioning. Zhang et al. (2022) found that 12 weeks of a specially designed physical activity intervention leads to significant improvement in working memory efficiency in preschool children, measured by the 1-back task. Importantly, the study identified positive correlations between working memory improvements and enhancements in balance and global motor competence, suggesting possible reciprocal relationships between motor and cognitive development. Chen et al. (2018), in a cross-sectional study, examined the relationship between motor competence and academic achievement and found positive associations between fundamental motor skills and indicators of academic performance. Although causality cannot be established from cross-sectional data, these findings support the hypothesis that motor competence development may contribute to broader educational outcomes through improved cognitive functioning and greater engagement in school activities.

3.6. Psychosocial Outcomes

Several studies examined psychosocial outcomes, including perceived motor competence, self-efficacy, and enjoyment in physical activity. Nicolosi et al. (2024) assessed perceived motor competence alongside actual motor skill performance, but the results regarding changes in perception were equivocal. This indicates the complexity of the relationship between actual and perceived competence, which may develop along different developmental trajectories. Gu et al. (2016) examined motivational aspects of physical activity interventions and found that programs incorporating teaching strategies that support autonomy and provide positive feedback enhance children's intrinsic motivation for physical activity. These findings emphasize the importance of intervention design that, in addition to skill development, encompasses motivational and affective dimensions of participation. Sgrò et al. (2019) investigated how different assessment approaches can influence children's motivation and engagement in physical education classes, suggesting that authentic, performance-based assessments may be more effective than traditional physical fitness tests in promoting positive attitudes toward physical activity.

3.7. Intervention Components and Characteristics

Successful interventions had several common characteristics. First, they provided adequate practice opportunities with developmentally appropriate activities tailored to children's skill levels. Second, they included diverse activities that maintained children's interest and engagement. Third, they were implemented by qualified teachers or extensive teacher training was provided to ensure high-quality delivery. Fourth, interventions often extended beyond the framework of traditional physical education classes through additional movement opportunities during recess, before and after school, or through family involvement. Kliziene et al. (2021) emphasized the importance of intervention implementation consistency and teacher preparation, finding that interventions delivered by well-trained instructors led to significantly better outcomes compared to those with minimal professional support. Similarly, Senturk et al. (2015) highlighted the role of instructor expertise in promoting motor development, particularly among younger children who require more individualized attention and feedback. Navarro-Patón et al. (2021)

showed that even relatively short interventions (6 weeks) can lead to significant improvements when specifically targeted at children with identified developmental needs, indicating that intensive and focused interventions may be particularly valuable in addressing developmental delays or disorders.

4. DISCUSSION

This review provides comprehensive evidence that school-based physical activity interventions can effectively enhance motor competence and promote health-relevant outcomes in children. The synthesis of 18 studies conducted over nearly two decades indicates consistent positive effects across different populations, settings, and intervention approaches, while simultaneously highlighting important nuances regarding optimal implementation strategies. Although the majority of included studies were rated as methodologically strong or moderate, the dominance of quasi-experimental designs should be taken into account when interpreting causal relationships.

4.1. Motor Competence Development as Foundation

Strong and consistent evidence of motor competence improvement across all studies supports theoretical frameworks that view motor competence as a fundamental element for engagement in physical activity and health throughout the lifespan (Stodden et al., 2008). The development of fundamental motor skills in childhood provides the "movement vocabulary" necessary for participation in various physical activities, sports, and games, potentially establishing positive physical activity trajectories that continue into adolescence and adulthood (Kriemler et al., 2011). The findings of Guo et al. (2024) and Nicolosi et al. (2024) indicate that not all motor skill development activities are equally effective. Structured and purposefully designed activities that incorporate elements of challenge, progression, and engagement show better outcomes compared to less structured approaches. This is consistent with contemporary pedagogical frameworks that emphasize the importance of task design, clarity of instruction, and appropriate progression in motor skill development (Lubans et al., 2010). The evidence that interdisciplinary approaches by Nicolosi et al. (2024) can enhance motor skill development compared to traditional methods points to possibilities for curricular innovations. Integrating motor skill development with academic content can help overcome time constraints while simultaneously supporting multiple educational objectives, which is particularly relevant in the context of increasing competition for instructional time in schools.

4.2. Physical Activity Promotion Beyond Physical Education

Although physical education classes represent an important setting for motor skill development, the findings of Costa et al. (2024) and other studies indicate that comprehensive approaches that encompass multiple movement opportunities throughout the school day achieve stronger effects compared to physical education classes alone. This finding is consistent with the Comprehensive School Physical Activity Program (CSPAP) frameworks, which advocate for integrated, whole-school approaches to physical activity promotion. The large study by Lo et al. (2017) provides important context for interpreting the contribution of physical education to overall physical activity levels. Although participation in physical education classes shows positive associations with activity levels, the strength of these associations suggests that physical education alone cannot ensure compliance with recommended daily physical activity guidelines. This emphasizes the need for complementary strategies, including active recess, active transportation to school, and initiatives involving family and community. The challenge of converting improved motor competence into long-term physical activity participation remains an important issue. Although improved motor skills theoretically facilitate engagement in physical activity, this process is not automatic and may depend on numerous factors, including social support, environmental opportunities, and motivational orientations. Future interventions should explicitly address these contextual factors to maximize the potential of motor competence for establishing lifelong physical activity patterns.

4.3. Health-Related Physical Fitness Outcomes

Consistent improvements in health-related physical fitness components across various studies provide encouraging evidence that school-based interventions can positively influence physiological indicators of children's

health. Improvements in cardiorespiratory fitness are particularly significant given the strong inverse association between fitness levels and risk factors for cardiovascular disease, metabolic syndrome, and overall mortality (Lee et al., 1999). The findings of Lämmle et al. (2016) regarding sustained improvements during long-term interventions are especially valuable, as they indicate that school programs can lead to lasting adaptations rather than merely transient effects. This has important implications for intervention design and resource allocation, supporting investment in long-term, comprehensive programs instead of short-term initiatives. However, the heterogeneity of fitness assessment methods among studies makes direct comparisons and meta-analyses difficult. Standardization of assessment protocols would enhance the ability to synthesize findings and establish dose-response relationships between intervention characteristics and fitness outcomes. Additionally, future research should examine whether fitness improvements translate into clinically significant changes in health indicators, such as blood pressure, lipid profile, and glucose metabolism.

4.4. Emerging Evidence on Cognitive Benefits

The preliminary evidence from Zhang et al. (2022) and Donnelly et al. (2016) regarding working memory improvement is particularly intriguing and consistent with a growing body of research indicating that physical activity enhances cognitive functioning through various mechanisms, including increased cerebral blood flow, neuroplasticity, and neurochemical adaptations. The observed correlations between motor competence improvements and cognitive enhancements suggest potentially synergistic relationships that merit further investigation. The cross-sectional associations between motor competence and academic achievement reported by Chen et al. (2018) further support integrated approaches that view physical and cognitive development as interconnected rather than competing priorities. However, longitudinal studies with robust designs are needed to establish causal relationships and identify the specific mechanisms underlying the observed associations. These findings have important implications for educational policy and practice. Evidence that physical activity interventions can support cognitive and academic outcomes may strengthen arguments for preserving or expanding physical education classes and physical activity opportunities in schools, particularly in contexts where such programs face budgetary or curricular pressures. Viewing physical activity as supporting rather than competing with academic goals may help secure institutional support and resources.

4.5. Technology-Assisted Interventions

The inconsistent results in studies examining exergaming and other technology-supported interventions indicate that such approaches are best viewed as supplements rather than replacements for conventional physical education instruction (Verstraete et al., 2007; Ye et al., 2018). Although exergaming may offer advantages such as greater engagement and accessibility, the available evidence does not support its superiority over well-designed traditional interventions in motor skill development. Nevertheless, technology-assisted approaches may have particular value for certain populations or contexts. For children with limited access to sports facilities, children with disabilities who have difficulty participating in traditional activities, or in environments with adverse climatic conditions, exergaming and similar technologies may represent valuable alternative movement opportunities. Future research should identify specific contexts and populations in which technology-assisted interventions have the greatest relative advantage.

4.6. Implementation Science Perspectives

The findings of Kliziene et al. (2021) and Senturk et al. (2015), which emphasize implementation quality and teacher preparedness, point to critical yet often overlooked aspects of intervention research. Efficacy under ideal research conditions does not guarantee effectiveness in real school environments, where resources, expertise, and implementation consistency may differ significantly. Implementation science frameworks, which systematically consider barriers and facilitating factors for intervention adoption, delivery, and sustainability, are essential for translating research findings into widespread practice. Teacher professional development emerges as a key lever for intervention success. Many teachers responsible for physical education instruction in lower elementary grades lack extensive training in motor development and physical activity pedagogy. Investment in continuous professional development programs, accessible teaching materials, and implementation support systems could significantly en-

hance the quality and impact of school-based interventions. Sustainability represents another crucial issue. Short-term research studies, even when successful, do not guarantee long-term program implementation after research support concludes. Future research should explicitly examine factors that support sustainable implementation, including administrative support, resource allocation, community partnerships, and integration with existing school priorities and systems.

4.7. Methodological Considerations and Limitations

Several methodological limitations should be taken into account. First, the dominance of quasi-experimental designs limits causal inferences, and future research should prioritize RCT designs whenever feasible. Second, the heterogeneity of outcome measures makes comparisons across studies difficult, and establishing standardized outcome sets would facilitate the synthesis of findings. Third, publication bias likely affects the available evidence base as studies with negative findings are published less frequently, requiring cautious interpretation of predominantly positive results. Fourth, most studies assessed immediate outcomes (motor skills, fitness) with limited examination of long-term effects on sustained physical activity participation, health status, or quality of life, which emphasizes the need for longitudinal research.

4.8. Implications for Practice and Policy

The accumulated evidence supports several key recommendations. First, schools should prioritize motor competence development through curricula that provide sufficient time for learning fundamental motor skills with appropriate progression. Second, comprehensive approaches that include active recess, classroom breaks, active transportation to school, and family engagement are more effective than isolated interventions, and schools should adopt whole-school approaches aligned with CSPAP frameworks. Third, investments in teacher professional development are essential, encompassing content knowledge and pedagogical approaches with ongoing support. Fourth, policies must ensure adequate time allocation—at least 150 minutes weekly for elementary school students. Fifth, systematic screening and multi-tiered intervention systems can ensure that all children, including those with motor difficulties, receive appropriate support and developmental opportunities.

4.9. Future Research Directions

Several research priorities require attention. First, it is necessary to examine dose-response relationships to optimize intervention duration, frequency, and intensity. Second, longitudinal studies should clarify the mechanisms linking motor competence with long-term health outcomes, identifying key mediators and moderators. Third, direct comparisons of different approaches using standardized assessment protocols would provide clear guidance for selecting the most effective strategies. Economic cost-effectiveness analyses, encompassing direct costs and long-term health savings, are essential for policy-level decision-making. Finally, research must examine effect variability among demographic groups and identify strategies for reducing inequalities, ensuring that all children benefit equally from school-based physical activity programs.

4.10. Study Limitations

This scoping review has several important limitations that should be considered when interpreting the findings.

Language bias: The search was limited to articles published in English, which may exclude relevant studies published in other languages, particularly in countries where English is not the primary language of scientific communication. This may lead to Anglocentric bias in the synthesis of findings and potentially overlook interventions developed and evaluated in non-Anglophone contexts.

Database selection: Although four major electronic databases were used (PubMed, Web of Science, Scopus, Google Scholar), the inclusion of Google Scholar as a source of "grey literature" may introduce quality bias, given that this platform contains articles that have not undergone rigorous peer review. Nevertheless, we decided to include Google Scholar to encompass a broader spectrum of evidence, particularly from underrepresented geographical areas.

Measurement heterogeneity: Significant heterogeneity in motor competence assessment instruments (e.g., TGMD-2, MABC-2, KTK, Eurofit) and different construct definitions makes direct comparison of findings across studies difficult. This heterogeneity precludes quantitative meta-analysis and requires caution in generalizing conclusions. Different instruments assess different aspects of motor competence (e.g., product vs. process skills), which may lead to different conclusions about intervention effectiveness.

Intervention heterogeneity: Studies included a broad spectrum of interventions (physical education, structured programs, exergaming) with varying durations (6 weeks to 2 years), frequency, and intensity. This variability makes it difficult to identify specific intervention components that are most effective for improving motor competence.

Despite these limitations, this scoping review provides a comprehensive overview of existing literature on school-based motor competence interventions and identifies key directions for future research.

5. CONCLUSION

This review provides strong evidence that school-based physical activity interventions effectively enhance motor competence and health-relevant outcomes in children. The consistency of positive findings across different settings and populations confirms the importance of schools as key sites for physical activity promotion. Despite methodological limitations, the accumulated evidence justifies continued investment in high-quality school programs. Motor competence development in childhood represents an investment in lifelong health. By providing all students with opportunities to develop fundamental motor skills, schools contribute to positive health trajectories that extend beyond childhood. As obesity rates rise and physical activity levels decline, school programs offer a scalable and equitable evidence-based approach. From a public health perspective, interventions focused on motor competence are not optional enrichment activities, but essential components of children's health promotion strategies.

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