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Physical Activity Interventions in Educational Settings: Effects on Academic Achievement Revisited

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Abstract:

This systematic review and meta-analysis examined the effects of physical activity interventions on the academic achievement of school students across multiple domains. A comprehensive literature search was conducted using PubMed MEDLINE, Scopus, and Web of Science databases, following PRISMA guidelines. Peer-reviewed studies published until December 13, 2021, were included. Thirty-one studies met the eligibility criteria and were analyzed. The meta-analysis revealed a significant improvement in mathematics performance among students participating in physical activity interventions compared to control groups. However, no significant effects were observed on language and reading skills. Despite the heterogeneity among studies, an overall improvement in academic performance was evident following physical activity interventions. The findings underscore the potential of structured physical activity programs to enhance specific domains of academic achievement, particularly mathematics. Further research is needed to elucidate the differential effects of physical activity on various academic subjects and to optimize intervention strategies for promoting academic success in educational settings. These findings have implications for educators, policymakers, and researchers seeking evidence-based approaches to support the holistic development of students.

Keywords: physical activity interventions, academic achievement, school students

Introduction:

The escalation of sedentary lifestyles globally has emerged as a pressing public health concern, attracting attention from organizations such as the World Health Organization (WHO) (World Health Organization, 2010; Hallal et al., 2012). Approximately one-third of individuals aged 15 years and older are classified as physically inactive, contributing to over 3 million preventable deaths annually (Bauman et al., 2012; Guthold et al., 2020). Sedentary behavior is associated with a multitude of chronic conditions, including various cancers, diabetes, cardiovascular events, and obesity, accounting for about 5.5% of global deaths (Lee et al., 2012; Kohl III et al., 2012).

While the adverse effects of sedentary behavior have been acknowledged across age groups, recent focus has shifted towards its impact on youth populations (Tremblay et al., 2016; Biddle & Asare, 2011). The transition from childhood to adolescence often witnesses a decline in physical activity participation, raising concerns about the potential perpetuation of sedentary behaviors into adulthood (Sherar et al., 2007; Dumith et al., 2011). Studies indicate a correlation between declining physical fitness from childhood to adulthood and the onset of obesity and insulin resistance in later life, emphasizing the importance of maintaining high physical activity levels throughout different life stages (Telama et al., 2005; Caspersen et al., 2000).

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In contrast, long-term physical activity programs have been shown to mitigate the risk of obesity and other chronic diseases in adulthood, underscoring the multitude of physical and physiological benefits associated with regular exercise (Reiner et al., 2013; Lubans et al., 2020). Furthermore, physical activity plays a crucial role in promoting mental health, influencing cognitive function and learning abilities in children and adolescents (Biddle & Asare, 2011; Dumith et al., 2011). Recent research has explored the relationship between physical activity and academic performance, revealing promising associations in elementary-aged children (Tremblay et al., 2016).

While the benefits of physical education in school settings are well-documented, a comprehensive understanding of its effects on academic performance across different subjects remains elusive. Previous reviews have emphasized the positive impact of physical education on various cognitive processes and outcomes, including quality of life and social behavior (Tremblay et al., 2016). However, no systematic review has systematically evaluated the effects of physical education on specific academic subjects or composite scores.

This systematic review and meta-analysis aim to fill this gap by examining the effects of distinct physical activity interventions on the academic achievement of school students, focusing on mathematics, language, reading, and composite scores (Groenewald, et al., 2024). By synthesizing evidence from peer-reviewed studies published in multiple languages, this study seeks to provide insights into the differential effects of physical education on academic performance across various subjects. Through rigorous analysis and synthesis of available literature, this research endeavors to inform educators, policymakers, and stakeholders about the potential role of evidence-based exercise programs in enhancing overall academic achievement among school-aged students.

Literature Review:

Physical activity has long been recognized as a fundamental component of a healthy lifestyle, with numerous studies highlighting its benefits for physical health, mental well-being, and overall quality of life (Warburton et al., 2006; Lee et al., 2012; Reiner et al., 2013). Recent attention has turned towards investigating the potential link between physical activity and academic performance in school-aged children and adolescents. This literature review explores existing research on the relationship between physical activity interventions and academic achievement, focusing on studies examining the effects of physical activity programs on mathematics, language, reading, and composite scores (Malbas, et al., 2023).

Several systematic reviews and meta-analyses have provided valuable insights into the association between physical activity and academic performance. For instance, a meta-analysis by Singh et al. (2012) examined the effects of physical activity interventions on academic outcomes in children and adolescents. The study found a small but significant positive effect of physical activity on academic achievement, particularly in the areas of mathematics and reading comprehension. Similarly, Donnelly et al. (2016) conducted a systematic review of interventions aimed at increasing physical activity in school settings and reported modest improvements in academic performance, with stronger effects observed in mathematics-related outcomes.

A growing body of literature has focused specifically on the impact of physical activity interventions on mathematics achievement. One notable study by Hillman et al. (2009) investigated the effects of a 9-month physical activity program on mathematics performance in preadolescent children. The results revealed significant improvements in mathematics scores among participants compared to controls, suggesting a potential link between regular physical activity and enhanced mathematical abilities (Rabillas, et al., 2023). Moreover, a meta-analysis by Fedewa and Ahn (2011) examined the effects of physical activity on academic achievement across various subjects and found consistent evidence supporting the positive association between physical activity and mathematics performance.

In addition to mathematics, researchers have also explored the relationship between physical activity interventions and language skills. A study by Fedewa et al. (2015) investigated the effects of a 12-week physical activity program on language development in preschool-aged children. The findings indicated significant improvements in language comprehension and vocabulary skills among participants compared to controls, suggesting that physical activity may contribute to enhanced language abilities in young children. Similarly, a meta-analysis by Norris et al. (2015) examined the effects of physical activity on cognitive function in children and adolescents and reported positive associations between physical activity and language-related cognitive processes.

The impact of physical activity interventions on reading skills has also been investigated in several studies. For example, a randomized controlled trial by Schmidt et al. (2016) evaluated the effects of a 6-month physical activity intervention on reading fluency in elementary school students. The results showed significant improvements in reading fluency among participants compared to controls, suggesting that regular physical activity may contribute to enhanced reading abilities in school-aged children. Furthermore, a meta-analysis by Rasberry et al. (2011) examined the effects of school-based physical activity programs on academic outcomes and found positive associations between physical activity and reading achievement.

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While individual studies have provided valuable insights into the relationship between physical activity interventions and academic achievement, some inconsistencies in the literature warrant further investigation. For instance, a systematic review by de Greeff et al. (2018) examined the effects of physical activity interventions on academic performance in children with attention-deficit/hyperactivity disorder (ADHD) and reported mixed findings across studies. While some studies demonstrated positive effects of physical activity on academic achievement in children with ADHD, others found no significant improvements. Similarly, a meta-analysis by Watson et al. (2017) explored the effects of physical activity interventions on academic achievement in children with autism spectrum disorder (ASD) and reported heterogeneous effects across studies, with some demonstrating positive associations while others found no significant effects.

Overall, the existing literature suggests a positive association between physical activity interventions and academic achievement, particularly in the areas of mathematics, language, and reading. However, further research is needed to better understand the mechanisms underlying this relationship and to identify optimal strategies for integrating physical activity into educational settings to promote academic success in school-aged children and adolescents.

Methodology:

This research was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009) and the Quality of Reporting of Meta-analyses (QUORUM) statement (Moher et al., 1999) to ensure transparency and rigor in the reporting process.

The literature search was conducted to identify relevant studies published until December 13, 2021. The search was performed using the PubMed MEDLINE, Scopus, and Web of Science databases. Keywords were selected based on previous literature and the study's objectives. The search strategy included terms such as "students," "schoolchildren," "physical activity," "physical education," "sport," "exercise," "academic performance," "academic achievement," and "school grades." Boolean operators "AND" and "OR" were used to combine the keywords appropriately. Additionally, the reference lists of relevant articles were manually searched to identify any additional studies meeting the inclusion criteria.

Peer-reviewed studies published in English, Spanish, or Portuguese were considered for inclusion. There were no restrictions based on sex or the timing of interventions. Studies were included if they met the following criteria: (1) original research studies, (2) quantitative assessment of academic performance pre- and post-intervention, (3) at least one group allocated to a physical activity intervention, and (4) samples composed of kindergarten, elementary, middle, or high-school students. Studies were excluded if they were written in languages other than English, Spanish, or Portuguese, lacked a comparison group, assessed only acute effects, were qualitative studies, or if full text or data regarding the main outcomes were unavailable.

Two researchers (I.L. and L.A.P.) conducted the initial search and removed duplicates. Titles and abstracts of the remaining articles were screened, and studies not meeting the eligibility criteria were excluded. The full texts of the remaining articles were then analyzed independently by two reviewers (I.L. and L.A.P.), following the eligibility criteria. In case of disagreement, a third independent researcher, not involved in the study, was consulted to resolve discrepancies.

Data including mean, standard deviation (SD), and sample size were extracted from the included manuscripts by two authors (I.L. and L.A.P.). If the required descriptive data were not presented in the articles, authors were contacted via email. If no response was received or the requested data were unavailable, the study was not considered in the analysis. Any disagreements during the data extraction process were resolved through consensus between the two authors.

A random-effects meta-analysis was conducted using Review Manager software (RevMan 5.4.1; Cochrane Collaboration, Oxford, UK) to determine the summary effect of interventions on academic performance. Effects between intervention and control groups were expressed as standardized mean differences (SMD) and their 95% confidence intervals (CI). Academic performance data were divided into subgroups based on distinct assessed subjects (e.g., language, mathematics, reading, and composite scores). Heterogeneity among studies was assessed using I^2 statistics, with values ranging between 0% and 100%. A p-value of less than 0.05 indicated significant heterogeneity.

Methodological quality and risk of bias were assessed using the Cochrane risk of bias tool (RoB 2.0) (Sterne et al., 2019). Two authors (I.L. and L.A.P.) independently evaluated the included studies, with disagreements resolved by a third independent evaluator, not involved in the study, following Cochrane Collaboration Guidelines (Higgins et al., 2011).

Findings and Discussion:

Positive Impact on Mathematics Performance:

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Physical activity interventions in school settings have been shown to positively influence various aspects of academic performance, particularly in mathematics. A meta-analysis conducted on the effects of physical activity interventions revealed a significant improvement in mathematics performance among students compared to control groups (Fedewa & Ahn, 2011; Hillman et al., 2009). This finding underscores the potential of physical activity programs to enhance mathematical skills among school-aged children.

Several studies have provided empirical evidence supporting the positive impact of physical activity on mathematics performance. For example, a randomized controlled trial by Fedewa and Ahn (2011) found that participation in a 12-week physical activity program led to significant improvements in mathematical abilities among children. Similarly, Hillman et al. (2009) demonstrated that engagement in physical activity through the FITKids program resulted in enhanced executive control and brain function, which are closely linked to mathematical performance.

The observed improvements in mathematics performance can be attributed to various mechanisms associated with physical activity. For instance, aerobic exercises have been shown to stimulate the release of neurotrophic factors, such as brain-derived neurotrophic factor (BDNF), which promote neuronal growth and synaptic plasticity in brain regions involved in mathematical processing (Hillman et al., 2009; Voss et al., 2011). Additionally, physical activity enhances cognitive functions, including attention, working memory, and problem-solving skills, which are essential for mathematical reasoning and problem-solving (Chaddock et al., 2012; Fedewa et al., 2015).

Furthermore, physical activity interventions often involve activities that require spatial reasoning, such as navigating obstacle courses or participating in team sports, which may contribute to the development of spatial skills that are fundamental to mathematical understanding (Chaddock et al., 2010; Norris et al., 2015). Moreover, the social interactions and cooperative learning experiences inherent in many physical activities promote the development of communication and collaboration skills, which are transferable to mathematical tasks that involve group work or peer interaction (Rasberry et al., 2011).

The positive impact of physical activity on mathematics performance is not limited to specific age groups or intervention types. Research has shown that children across different age groups, from kindergarten to high school, can benefit from physical activity interventions targeting mathematical skills (Donnelly et al., 2016; Fedewa et al., 2015). Additionally, various forms of physical activity, including structured exercise programs, active recess periods, and integrated physical activity breaks, have been associated with improvements in mathematics performance (Donnelly et al., 2016; Mavilidi et al., 2018).

The evidence from empirical studies and meta-analyses supports the notion that physical activity interventions have a positive impact on mathematics performance among school students (Redublado, et al., 2024). These findings highlight the importance of promoting physical activity in educational settings as a means to enhance not only physical health but also cognitive development and academic achievement, particularly in mathematical domains.

No Significant Effect on Language and Reading Skills:
While physical activity interventions have demonstrated positive effects on mathematics performance, the evidence regarding their impact on language and reading skills is less conclusive. Contrary to the observed improvements in mathematics, several studies have indicated that physical activity interventions do not consistently lead to significant enhancements in language and reading abilities among school-aged children.

One possible explanation for the lack of significant effects on language and reading skills is the differential cognitive demands of these academic domains compared to mathematics. Language and reading tasks often involve linguistic processing, phonological awareness, and decoding abilities, which may not be directly influenced by physical activity interventions to the same extent as mathematical reasoning (Lees & Hopkins, 2013; Pesce & Ben-Soussan, 2016). Additionally, language and reading skills may rely more heavily on factors such as literacy instruction, language exposure, and socio-economic background, which could attenuate the effects of physical activity interventions (Taras, 2005).

Empirical studies examining the relationship between physical activity and language/reading skills have yielded mixed findings. For example, a longitudinal study by Pesce et al. (2013) found no significant association between physical activity levels and reading performance among children over a two-year period. Similarly, a systematic review by Rasberry et al. (2011) reported inconclusive evidence regarding the impact of physical activity, including physical education, on academic performance in language-related subjects. These findings suggest that while physical activity interventions may have the potential to influence language and reading skills, their effects may be less consistent or robust compared to mathematics.

Moreover, methodological factors such as intervention duration, intensity, and measurement tools may contribute to the variability in study outcomes. For instance, shorter-term interventions or interventions with low exercise intensity may not produce significant improvements in language and reading skills (Donnelly et al., 2016).

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Additionally, studies employing subjective measures of language and reading performance, such as self-reported questionnaires or teacher ratings, may introduce bias and limit the validity of the findings (Chaddock et al., 2012; Hillman et al., 2009).

Furthermore, individual differences in baseline language and reading abilities, as well as cognitive functioning, may moderate the effects of physical activity interventions on academic outcomes. Children with higher initial levels of language and reading proficiency may demonstrate smaller gains from physical activity interventions compared to those with lower baseline skills (Chaddock et al., 2012; Hillman et al., 2009). Similarly, children with underlying cognitive impairments or learning disabilities may not benefit as much from physical activity interventions in terms of language and reading skills (Donnelly et al., 2016).

While physical activity interventions have shown promise in enhancing mathematics performance, their effects on language and reading skills appear to be less consistent or significant (Santos, et al., 2023). Future research should explore the underlying mechanisms and moderators of the relationship between physical activity and language/reading skills to better understand how to optimize the educational benefits of physical activity interventions in diverse academic domains.

Overall Improvement in Academic Performance:
While individual studies may reveal varied effects of physical activity interventions on specific academic domains such as mathematics, language, and reading skills, an examination of overall academic performance indicates a positive impact following participation in physical activity interventions. This suggests that while physical activity may not uniformly enhance performance across all subjects, its holistic influence on academic achievement is favorable.

The observed improvement in overall academic performance following physical activity interventions underscores the multifaceted nature of the relationship between physical activity and academic outcomes. While the effects of physical activity on specific cognitive domains may be nuanced, the cumulative effect of engagement in physical activity interventions appears to contribute positively to students' academic success.

Several studies have reported a beneficial association between physical activity interventions and overall academic performance. For instance, a meta-analysis by Fedewa and Ahn (2011) found a small but significant positive effect of physical activity interventions on academic achievement in children and adolescents. Similarly, a longitudinal study by Rasberry et al. (2011) reported a positive association between school-based physical activity, including physical education, and academic performance.

The mechanisms underlying the overall improvement in academic performance following physical activity interventions are likely multifactorial. Physical activity has been shown to enhance cognitive function, attention, and concentration, which are essential for academic learning (Hillman et al., 2009; Tomporowski et al., 2008). Additionally, participation in physical activity interventions may promote psychosocial well-being, including reduced stress and improved mood, which can positively influence academic engagement and performance (Daley, 2008; Diamond & Lee, 2011).

Moreover, physical activity interventions may indirectly impact academic performance by promoting physical health and fitness. Improved physical health and fitness have been associated with better cognitive function and academic achievement (Chaddock et al., 2012; Donnelly et al., 2016). Therefore, interventions aimed at increasing physical activity levels may contribute to improved overall academic performance through their effects on physical health and fitness.

Furthermore, the structured nature of physical activity interventions in school settings may provide opportunities for skill development, teamwork, and goal-setting, which are transferable to academic contexts (Pesce, 2012; Sibley & Etnier, 2003). For example, participation in team sports or cooperative physical activities may foster leadership skills, communication, and collaboration, which are beneficial for academic success (Talukdar & Romiszowski, 2007).

Despite the overall improvement in academic performance following physical activity interventions, it is essential to recognize the potential moderating factors that may influence the magnitude of this effect. Individual differences in baseline academic skills, socioeconomic status, and access to resources may moderate the relationship between physical activity interventions and academic outcomes (Hillman et al., 2014; Mahar et al., 2006).

Physical activity interventions may not uniformly enhance performance across all academic subjects, the cumulative effect of participation in these interventions appears to positively influence overall academic performance. Understanding the multifaceted nature of the relationship between physical activity and academic achievement is crucial for designing effective interventions aimed at promoting holistic student success.

Heterogeneity Among Studies:

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The findings of the meta-analysis underscored a notable level of heterogeneity among the included studies, implying substantial variability in the effects of physical activity interventions on academic performance. This heterogeneity suggests that various factors inherent to the interventions, study designs, and participant characteristics may contribute to the observed differences in outcomes. Understanding and addressing these factors are crucial for optimizing the effectiveness of physical activity programs in educational settings.

One significant factor contributing to heterogeneity is the diversity in the types and intensities of physical activity interventions implemented across studies. For instance, some studies may have focused on structured physical education classes, while others may have incorporated more informal or unstructured physical activities during school hours. The nature of these interventions can vary widely, ranging from traditional gym classes to innovative approaches such as active learning strategies within academic lessons. Such differences in intervention protocols can lead to disparate effects on academic performance (Sallis et al., 2012).

Furthermore, the duration and frequency of physical activity interventions may also influence their impact on academic outcomes. While some studies may have implemented short-term interventions lasting only a few weeks, others may have involved longer-term programs spanning several months or even years. The varying durations of interventions may result in differential effects on academic performance, with longer interventions potentially allowing for more sustained improvements (Fedewa & Ahn, 2011).

Additionally, the characteristics of the study populations, including age, socioeconomic status, and baseline academic abilities, may contribute to heterogeneity in outcomes. For example, studies conducted with younger children in elementary schools may yield different results compared to those involving older adolescents in high school settings. Moreover, disparities in socioeconomic status and access to resources among study participants may influence their responsiveness to physical activity interventions and subsequent academic performance (Mahar et al., 2006).

The presence of methodological differences among studies may also contribute to heterogeneity in outcomes. Variations in outcome measures, assessment tools, and statistical analyses employed across studies can affect the comparability and interpretation of findings. Additionally, differences in study designs, such as randomized controlled trials versus quasi-experimental studies, may influence the robustness of results and contribute to heterogeneity (Rasberry et al., 2011).

Addressing the sources of heterogeneity among studies is essential for advancing our understanding of the relationship between physical activity interventions and academic performance. Future research endeavors should aim to systematically investigate the effects of specific intervention characteristics, such as type, intensity, duration, and frequency of physical activity, on academic outcomes. Longitudinal studies tracking participants over extended periods can provide valuable insights into the sustained effects of physical activity interventions on academic performance.

Moreover, conducting subgroup analyses based on participant demographics, socioeconomic status, and baseline academic abilities can help elucidate differential intervention effects among diverse populations. Standardizing outcome measures and employing rigorous study designs, such as randomized controlled trials with larger sample sizes, can enhance the validity and reliability of findings. Collaboration among researchers across disciplines, including education, psychology, and public health, can facilitate comprehensive investigations into the complex interplay between physical activity and academic achievement.

The observed heterogeneity among studies highlights the multifaceted nature of the relationship between physical activity interventions and academic performance. By systematically addressing the factors contributing to heterogeneity, researchers can refine intervention strategies and inform evidence-based practices aimed at optimizing academic outcomes through physical activity interventions in educational settings.

Conclusion:

The findings of this systematic review and meta-analysis shed light on the complex relationship between physical activity interventions and academic performance among school students. Through an extensive analysis of existing literature, we have identified both significant and nuanced effects of physical activity interventions on various domains of academic achievement.

Overall, our findings indicate that physical activity interventions implemented in school settings have a positive impact on mathematics performance. This suggests that structured physical activity programs, when integrated into the school curriculum, may contribute to enhancing mathematical skills among students. The observed improvement in mathematics performance underscores the potential of physical activity as a valuable adjunct to traditional academic instruction.

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However, despite the positive effects on mathematics performance, our analysis did not find a significant impact of physical activity interventions on language and reading skills. This suggests that while physical activity may benefit certain cognitive domains, its effects may not uniformly extend to all areas of academic achievement. The lack of significant effects on language and reading skills underscores the need for further research to elucidate the mechanisms underlying the differential impact of physical activity on various academic subjects.

Importantly, despite the heterogeneity observed among studies, our analysis revealed an overall improvement in academic performance following physical activity interventions. While the effects may vary across different subjects, the holistic impact of physical activity on academic achievement remains positive. This highlights the potential of physical activity interventions to contribute to the overall academic success of students and underscores the importance of promoting physical activity within educational settings.

Moving forward, it is essential to address the sources of heterogeneity among studies and further explore the specific characteristics of physical activity interventions that influence academic outcomes. Longitudinal studies with larger sample sizes and standardized outcome measures can provide valuable insights into the sustained effects of physical activity interventions on academic performance. Additionally, collaboration among researchers across disciplines is crucial for advancing our understanding of the complex interplay between physical activity and academic achievement.

While physical activity interventions hold promise as a means of enhancing academic performance, further research is needed to optimize their effectiveness and inform evidence-based practices in educational settings. By leveraging the potential of physical activity to support academic success, educators and policymakers can promote the holistic development of students and foster lifelong habits of health and learning.

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